ORTHOPEDIC PHYSICAL THERAPY ASSESSMENT

We want to know

1. **The objectives of orthopedic physical therapy assessment.**
2. **When we should assess patients?**
3. **Systems Review**
4. **Subjective assessments. (history of present condition, area of symptom, severity of symptoms, duration, aggravating and easing factors, SIN, previous treatment and investigations, previous treatment and investigations, past medical history)**
5. **Objective assessment (Gait, inspection, palpation, ROM, differentiation tests, neurological tests)**

Orthopedic physical therapists diagnose, manage, and treat disorders and injuries of the musculoskeletal system as well as rehabilitate patients post orthopedic surgery. Those who have suffered injury or disease affecting the muscles, bones, ligaments, or tendons of the body will benefit from assessment by a physical therapist specialized in orthopedic

The objectives of orthopedic physical therapy assessment are

- To identify the appropriate questions to include in a subjective musculoskeletal assessment.
- To discuss the use of regional and special questions for particular joints.
- To explain the use of appropriate subjective and objective markers.
- To explain the use of specific and regional tests at particular joints.
- To recognize the need for continuous reassessment.

When we should assess patients?

- **On first patient contact**, it is essential to perform an initial assessment to determine the patient's problems and to establish a treatment plan.
- **During the treatment**, assessment is particularly appropriate while performing treatments such as mobilisations and exercises when the patient's signs and symptoms may vary quite rapidly. Be

aware of any improvement or deterioration in the patient's condition as and when it occurs

- **Following each treatment**, the patient should be reassessed using subjective and objective markers in order to judge the efficacy of the physiotherapy intervention. Assessment is the keystone of effective treatment without which successes and failures lose all of their value as learning experiences.
- **At the beginning of each new treatment**, assessment should determine the lasting effects of treatment or the effects that other activities may have had on the patient's signs and symptoms. In reassessing the effect of a treatment, it is essential to evaluate progress from the perspective of the patient, as well as from the physical findings.

The assessment form includes:

- ***Listen*** – history and background.
- ***Look*** – observation.
- ***Test*** – individual structures (range of movement, strength).
- ***Record*** – an accurate account of findings.
- ***Assess*** – and remember to involve the patient

Systems Review

The systems review includes the following components:

All Major Body Systems	*Review of Systems:* component of the Health History to determine need for referral for additional medical evaluation
Cardiovascular/pulmonary	Shortness of breath, pressure or pain in the chest, pulsating pain, history of heart or lung disease
Endocrine	History of thyroid or other hormonal conditions, medications
Eyes, Ears, Nose, and Throat	History of surgery or use of adaptive equipment
Gastrointestinal	Heartburn, reflux, diarrhea, constipation, vomiting, severe abdominal pain, swallowing problems
Genitourinary/reproductive	Bowel or bladder function, burning with urination, sexual function, unusual menstrual cycles, pregnancy
Hematological or lymphatic	Results of recent bloodwork or treatment, bleeding or lymphedema
Integumentary	History of skin cancer, dermatological conditions (eczema, psoriasis, etc.), lumps or growths
Neurological/musculoskeletal	History of CNS or peripheral nerve symptoms, muscular cramping, spasms, atrophy, weakness
Overall physical and emotional well-being	Persistent fatigue, malaise, fever, chills, sweats, unexplained weight change, depression, mood swings, suicidal thoughts
Human Movement System	***Systems Review:* component of the hands-on Examination specific to systems affecting movement**
Cardiovascular/pulmonary	Heart rate and rhythm, respiratory rate, blood pressure, and edema
Integumentary	Skin temperature, color, texture, integrity, scar formation, wound or incision healing
Musculoskeletal	Symmetry, gross ROM and strength, height and weight
Neuromuscular	General assessment of gross coordinated movement (e.g., balance, gait, locomotion, transfers, transitions) and motor function (motor control, motor learning)
Communication ability, affect, cognition, language, learning style	Ability to make needs known, consciousness, orientation (person, place, time), expected emotional/behavioral responses, learning preferences (e.g., learning barriers, educational needs)

For the cardiovascular/pulmonary system, the assessment of heart rate, respiratory rate, blood pressure, and edema. There are four so-called **vital signs** that are standard in most medical settings: temperature, heart rate, blood pressure, and respiratory rate. **Pain** is considered by many to be a **fifth vital sign**. The clinician should monitor at least heart rate and blood pressure in any person with a history of cardiovascular disease or pulmonary disease, or those at risk for heart diseases

"**Temperature**. Body temperature is one indication of the **metabolic state** of an individual; measurements provide information concerning basal metabolic state, possible presence or absence of infection, and metabolic response to exercise. , ,**Normal body temperature** of the adult is 98.4_F(37_C). However, a temperature in the range of 96.5–99.4_F (35.8–37.4_C) is not at all uncommon. **Fever or pyrexia** is a temperature exceeding 100_F (37.7_C).82 **Hyperpyrexia** refers to extreme elevation of temperature above 41.1_C (or 106_F).81 **Hypothermia** refers to an abnormally low temperature (below 35_C or 95_F). The temperature is generally taken by placing the bulb of a thermometer under the patient s tongue for 1–3 minutes, depending on the device. In most individuals, there is a diurnal (occurring everyday) variation in body temperature of 0.5–2_F. The lowest ebb is reached during sleep. **Menstruating women** have a well-known temperature pattern that reflects the effects of ovulation, with the **temperature dropping** slightly **before menstruation**, and then **dropping further 24–36 hours prior to ovulation.** Coincident **with ovulation**, the **temperature rises** and remains at a somewhat higher level until just before the next menses. It is also worth noting that in **adults older than 75 years of age** and in those who are immunocompromised (e.g., transplant recipients, corticosteroid users, persons with chronic renal insufficiency, or anyone taking excessive antipyretic medications), **the fever response may be blunted or absent Heart rate**. In most people, the pulse is an accurate measure of heart rate. The heart rate or pulse is taken to obtain information about the resting state of the cardiovascular system and the system response to activity or exercise and recovery. It is also used to assess patency of the specific arteries palpated and the presence of any irregularities in the rhythm. When the heart muscle contracts, blood is ejected into the aorta and the aorta stretches. At this point, the wave of distention (pulse wave) is most pronounced, but relatively slow moving (3–5 m/s). As it travels toward the peripheral blood vessels, it gradually diminishes and becomes faster. **In the large arterial branches, its velocity is 7–10 m/s; in the small arteries, it is 15–35 m/s.** When taking a pulse, the fingers must be placed near the artery and pressed gently against a firm structure, usually a bone. The pulse can be taken at a number of points. The most accessible is usually the **radial pulse,** at the distal aspect of the radius. Sometimes, the pulse cannot be taken at the wrist and is taken at the elbow **(brachial artery**), at the neck against the carotid artery **(carotid pulse),** behind the knee **(popliteal artery**), or in the foot using **the dorsalis pedis or posterior tibial arteries.** The pulse rate can also be measured by listening directly to the heart beat, using a stethoscope. One should **avoid using the thumb** when taking a pulse, as it has its own pulse that can interfere with detecting the patient pulse. The normal adult heart rate is 70 beats per minute (bpm), with a range of 60–80 bpm. A rate of greater than 100 bpm is referred to as **tachycardia**. Normal causes of tachycardia include anxiety, stress, pain, caffeine, dehydration, or exercise. A rate of less than 60 bpm is referred to as **bradycardia**. Athletes may normally have a resting heart rate lower than 60. The normal range of resting heart rate in children is between 80 and 120 bpm. The rate for a newborn is 120 bpm (normal range 70–170 bpm).

"**Respiratory rate**. The normal chest expansion difference between the resting position and the fully inhaled position is **2–4 cm (females > males)**. The clinician **should compare measurements** of both the anterior–posterior diameter and the transverse diameter during rest and at full inhalation. Normal respiratory rate is between 8 and 14 per minute in in adults and slightly quicker in children. The following breathing patterns are characteristic of disease & **Cheyne–Stokes respiration**, characterized by a periodic, regular, sequentially increasing depth of respiration, occurs with serious cardiopulmonary or cerebral disorders.

& Biot, s respiration, characterized by irregular spasmodic breathing and periods of apnea, is almost always associated with hypoventilation due to CNS disease.

& Kussmaul,s respiration, characterized by deep, slow breathing, indicates acidosis, as the body attempts to blow off carbon dioxide.

& Apneustic breathing is an abnormal pattern of breathing characterized by a postinspiratory pause. The usual cause of apneustic breathing is a pontine lesion.

& Paradoxical respiration is an abnormal pattern of breathing, in which the abdominal wall is sucked in during inspiration (it is usually pushed out). Paradoxical respiration is due to paralysis of the diaphragm.

"**Blood pressure**. Blood pressure is **a measure of vascular resistance to blood flow**. The normal adult blood pressure can vary over a wide range. The assessment of blood pressure provides **information about the effectiveness of the heart as a pump and the resistance to blood flow.** It is measured in mm Hg and is recorded in two numbers. **The systolic pressure** is the pressure that is exerted on the brachial artery when the heart is contracting, and **the diastolic pressure** is the pressure exerted on the artery during the relaxation phase of the cardiac cycle. The JNC 7 report released in May 2003 has added a new category of **prehypertension** and has established more aggressive guidelines for medical intervention of hypertension. The normal values for resting blood pressure in adults are:

- **normal:** systolic blood pressure <120mmHg and diastolic blood pressure <80 mm Hg;
- **prehypertension:** systolic blood pressure 120–139mmHg or diastolic blood pressure 80–90 mm Hg;

- **stage 1 hypertension**: systolic blood pressure 140–159mm Hg or diastolic blood pressure 90–99 mm Hg;
- **stage 2 hypertension**: systolic blood pressure _160 mm Hg or diastolic blood pressure _100 mm Hg.

The normal values for resting blood pressure in children are:

- **systolic:** birth to 1 month, 60–90 mm Hg; up to 3 years of age, 75–130 mm Hg; and over 3 years of age, 90–140 mm Hg;
- **diastolic:** birth to 1 month, 30–60mmHg; up to 3 years of age, 45–90mmHg; and over 3 years of age, 50–80mmHg.
- **Orthostatic hypotension** is defined as a drop in systolic blood pressure when assuming an upright position. Orthostatic hypotension can occur as a side effect of **antihypertensive medications** and in cases of low blood volume in patients who are **postoperative or dehydrated**, and in those with **dysfunction of the autonomic nervous system**, such as that which occurs with **a spinal cord injury or postcerebrovascular acciden**t. Activities that may increase the chance of orthostatic hypotension, such as application of **heat modalities, hydrotherapy, pool therapy, moderate-to vigorous exercise using the large muscles, sudden changes of position, and stationary standing, should be avoided** in susceptible patients. The normal systolic range generally increases with age. The pressure should be determined in both the arms. **Causes of marked asymmetry in blood pressure of the arms** include the following: **errors in measurements, marked difference in arm size, thoracic outlet syndromes, embolic occlusion of an artery, dissection of an aorta, external arterial occlusion, coarctation of the aorta, and atheromatous occlusion.**

Edema. Edema is an observable swelling from fluid accumulation in certain body tissues. Edema most commonly occurs in the feet and legs, where it is also referred to as **peripheral edema**. Swelling or edema may be localized at the site of the injury or diffused over a larger area. In general, the amount of swelling is related to the severity of the injury. However, in some cases, serious injuries produce very limited swelling, whereas, in others, minor injuries cause significant swelling. Edema occurs as a result of **changes in the local circulation and an inability of the**

lymphatic system to maintain equilibrium. The swelling is the result of the accumulation of excess fluid under the skin, in the interstitial spaces or compartments within the tissues that are outside of the blood vessels. Most of the body fluids that are found outside of the cells are normally stored in two spaces: the blood vessels (referred to as blood volume) and the interstitial spaces (referred to as interstitial fluid). Generally, the size of lymph nodes is dependent on the size of the drainage area. Usually, the closer the lymph node is to the spinal cord, the greater the size of the lymph node. The neck is the exception to the rule. In various diseases, excess fluid can accumulate in either one or both of the interstitial spaces or blood vessels. **An edematous limb indicates poor venous return.**

Pitting edema is characterized by an indentation of the skin after the pressure has been removed. A report of rapid joint swelling (within 2–4 hours) following a traumatic event may indicate bleeding into the joint. Swelling of a joint that is more gradual, occurring 8–24 hours following the trauma, is likely caused by an inflammatory process or synovial swelling.

The more serious reasons for swelling include fracture, tumor, congestive heart failure, and deep vein thrombosis.

" For the integumentary system, the assessment of **skin integrity, skin color, and presence of scar formation**. The integumentary system includes the skin, the hair, and the nails. The examination of the integumentary system may reveal manifestations of systemic disorders. The overall color of the skin should be noted. Cyanosis in the nails, the hands, and the feet may be a sign of a central (advanced lung disease, pulmonary edema, congenital heart disease, or low hemoglobin level) or peripheral (pulmonary edema, venous obstruction, or congestive heart failure) dysfunction.

Palpation of the skin, in general, should include assessment of temperature, texture, moistness, mobility, and turgor.

Skin temperature is best felt over large areas using the back of the clinician hand. An assessment should be made as to whether this is localized or generalized warmth.

- **Localized**. May be seen in areas of the underlying inflammation or infection.
- **Generalized.** May indicate fever or hyperthyroidism.

- **Skin texture** is described as smooth or rough (coarse).
- **Skin mobility** may be decreased in areas of edema or in scleroderma.

" **For the musculoskeletal system**, the assessment of gross symmetry, gross range of motion, gross strength, weight, and height.

"**For the neuromuscular system**, a general assessment of gross coordinated movement (e.g., balance, locomotion, transfers, and transitions). In addition, the clinician observes for peripheral and cranial nerve integrity and notes any indication of neurological compromise such as tremors or facial tics.

" **For communication ability**, **affect, cognition, language, and learning style,** the clinician notes whether the patient's communication level is age appropriate; whether the patient is oriented to person, place, and time; and whether the emotional and behavioral responses appear to be appropriate to his or her circumstances. It is important to verify that the patient can communicate their needs. The clinician should determine whether the patient has a good understanding of his or her condition, the planned intervention, and the prognosis. The clinician should also determine the learning style that best suits the patient.

Subjective Assessment

Goals of the subjective assessment

The goals of subjective assessment are **to gather all relevant information about the site, nature, behaviour and onset of symptoms, and past treatments. Review the patient's general health, any past investigations, medication and social history.** This should lead to a formulation of the next step of physical tests.

N:B **Symptoms** are what the person complains of (e.g. 'my knee hurts'). **Signs** are what can be measured or tested (e.g. the patient has a positive patellar tap test).

First questioning

Subjective assessment needs to include the name, address and telephone number of the patient, and the patient's hospital number, if appropriate. Both the age and the date of birth of the patient should be recorded. The medical referrer's name and practice should also be recorded for correspondence, discharge letters, etc.

Identify the patient's hobbies or interests. Is she/he able to participate in a sport if desired? If not, determine the reasons. Identify the length of time the patient has been off work or has been unable to participate in physical activities. Evaluate the progression of symptoms. If the person has not been participating in physical activities, and if no improvement has occurred it may be appropriate to advise a return to light training in order to prevent devitalisation of tissues and fear avoidance issues.

It is also essential for the physiotherapist to obtain sufficient details of the patient's employment. Is the patient currently working? If not, determine the reasons for this Is it because the person is unable to cope with the physical demands of the job? Do heavy lifting, repetitive movements or inappropriate sustained postures increase the symptoms? These factors may be precursors of poor posture and muscle imbalance, which may accentuate degenerative disease and increase symptoms. However, it is equally important to recognise that withdrawing from normal activities of daily life can result in deconditioning of musculoskeletal structures that may lead to degenerative disease and an increase in symptoms.

Present condition

- History of the present condition
- Insidious onset

Insidious onset means that the patient's symptoms appear without any obvious cause. An example of this would be a degenerative condition such as osteoarthritis. These types of conditions often begin with a small amount of stiffness and pain, which is characterised by exacerbation and remission but is, nonetheless, progressive.

Traumatic onset

Can the onset of symptoms be related to a particular injury? Identify if there was a definite cause for the patient's symptoms. The mechanism of injury may be indicative of the structures damaged. For example, a **valgus strain of the knee may stretch the medial collateral ligament of the knee**, **whereas forced rotation of the knee joint when in a semi-flexed weight-bearing position may tear the menisci.**

Progression of the condition

Are the patient’s symptoms getting better or worse? Acute soft-tissue injuries normally undergo a period of inflammation and repair, and symptoms may subside rapidly within a few days or weeks. However, progressive arthritic diseases may have a history of exacerbation and remission with a general increase in the severity or frequency of their symptoms, as the disease progresses.

Progression of the condition may indicate how quickly the patient’s symptoms will subsides. Chronicity or age of the condition How long has the patient experienced the symptoms? Is the condition acute or chronic? If the injury is chronic or

has not resolved completely, it may indicate a number of different causes, such as mechanical instability from a ligament disruption, functional instability because of weakened muscles, loss of proprioception (and therefore the loss of an inherently protective reflex mechanism at the joint) or malalignment. Furthermore, it may be developing into a degenerative condition.

Area of the symptoms

It is useful to record the area of the pain by using a body chart, because this affords a quick visual reference. The patient may complain of more thanone symptom, so the symptoms may be recorded or referred to individually as P1 and P2 and so on. Areas of anaesthesia or paraesthesia may be recorded differently on the pain chart – they may be represented as areas of dots in order to distinguish them from areas of pain (Figure 1).

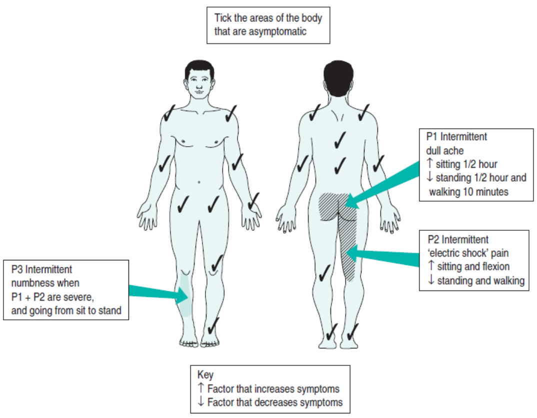


Figure.1 Typical body chart. In this example the patient’s details have been recorded.

Severity of the symptoms

The severity of the pain may be measured on **a visual analogue scale (VAS)** (Figure.2) or on a numerical scale of 0–10 to quantify the pain, where 0 stands for no pain at all and 10 is perceived by the patient as the worst pain imaginable. The mark on a VAS can then be measured and recorded for future comparisons using a ruler. Although these measures are not wholly objective, they do allow changes to be monitored as the treatment progresses.

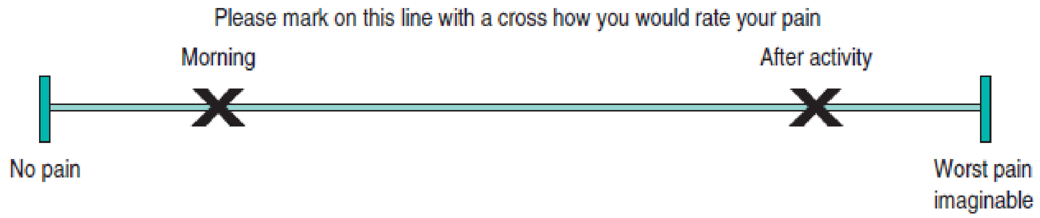


Figure.2 The visual analogue scale (VAS).

Duration of the symptoms

Establish whether the pain and symptoms are intermittent or constant. Is the pain present all of the time or does it come and go depending on activities or time of day? Aggravating and easing factors

Positional factors

Most musculoskeletal pain is mechanical in origin and is therefore made better or worse by adopting particular positions or postures that either stretch or compress the structure that is giving rise to the pain. Moreover, aggravating and easing movements may provide the physiotherapist with a clue as to the structure that is causing the pain. Various body or limb positions place different structures on stretch or compression and the resultant deformation produces an increase in severity of the pain. The aggravating and easing factors can be recorded on the pain chart, as in Figure.1. It is also necessary to record the length of time that engaging in aggravating activities produces an increase in symptoms or, alternatively, takes to settle down. This indicates the irritability of the patient's condition.

Time factors

It is useful to record the behaviour of signs and symptoms over a 24-hour period – the diurnal pattern. Do the symptoms keep the patient awake or awaken the person regularly during the night? Is this because of a particular sleeping posture or to other, unrelated factors? On arising, how are the symptoms for the first hour or so of the day and, moreover, do the symptoms vary from the morning to the afternoon and into the evening? Does this follow a particular pattern? This information can be included on the body chart.

Be careful not to confuse time of day with the performance of particular activities that the patient may undertake at that time. **Certain pathologies tend to be more painful at characteristic times of the day**. For example, **chronic osteoarthritic** changes are characteristically painful and stiff initially on arising from sleep, **intervertebral disc related pain** is often more painful on arising owing to the disc imbibing water during sleep and thus exerting pressure on pain-sensitive structures. Prolonged morning pain and stiffness, which improves only minimally with movement, suggests an **inflammatory process**

Determining the SIN factors

Once the severity of the symptoms and the aggravating and easing factors have been noted, it is then possible t determine the SIN factor of the condition: severity/ irritability/nature. SIN factors are used to guide the length and firmness of the objective assessment and subsequent treatment.

Severity

This can be quantified by **the VAS**, numerical scale or other valid pain questionnaire. It can be recorded as high (pain score of around 7–10), moderate (score around 4–6) or low(score around 1–3).

Irritability

This is the time that the person has to perform the activity to increase the pain and, conversely, how long it takes before the pain settles to its former intensity. It can be measured as either **high** (the aggravating factor causes pain to increase very quickly or instantly and then the pain takes a long time to settle back), **moderate** (the aggravating factor takes longer to increase the symptom) or **low** (the aggravating factor can be performed for a long time before exacerbating the patient's symptoms and then on stopping the activity the symptoms subside rapidly). An example of low irritability would be that the knee pain is aggravated after jogging for one hour and then subsides after one minute of rest.

Nature

It is possible to hypothesise the nature of the condition following the subjective history, i.e. whether the patient's condition has a predominantly **inflammatory, traumatic, degenerative or mechanical cause.**

The physiotherapist should identify the following:

1. Is this the first episode?
2. Is it recurrent?
3. Is it getting better or worse?

Previous treatments

Has the patient received any treatment for this condition in the past and, if so, was it effective? Was the improvement partial or total, and did it provide permanent or temporary relief? If the treatment has been effective in the past it may well help again. Be careful not to repeat unsuccessful interventions as they are unlikely to be therapeutic.

Investigations

Record the results of any investigations that the patient has undergone. Case notes, radiographic films and reports can be ordered and read, as patients may not always be a reliable source of the results of their investigations. **X-rays, MRI scans, CAT scans and bone scans**.Scans are now commonly used to aid the diagnosis of musculoskeletal disorders. X-rays are useful in that the show the degree or extent of arthritis present at a joint. They are also useful in determining the extent of osteomyelitis (bone infection) and some malignancies and osteoporosis. Moreover, they are valuable following trauma to identify fractures or dislocations. Be aware, however, that there is a poor correlation between X-rays and spinal symptoms for non-specific low back and neck pain. What is identified as pathological on these tests may not always be the structure responsible for the patient's signs and symptoms. Routine X-rays are not helpful in non-specific degenerative spinal disease. Computerised axial tomography (CAT) scans may be used to identify the precise level and extent of disc prolapse and subsequent nerve impingement prior to discectomy. Magnetic resonance imaging (MRI) may be used to identify ligamentous and muscular injuries, particularly in athletes, as well as discogenic prolapse. Bone scans are sensitive to 'hot spots' or areas of inflammation present in bone and may detect malignancy or diseases such as ankylosing spondylitis, some fractures and infection site

Blood tests

These are used extensively for the confirmation of the diagnosis of particular diseases such as **rheumatoid arthritis, ankylosing spondylitis, osteomyelitis and malignancy**

Other investigations

The patient may be undergoing investigations for other pathologies that could possibly relate to the musculoskeletal condition. These should be noted and recorded.

Past medical history

Determine whether or not the patient is suffering, or has suffered, any **major operations or illnesses**. These may affect the vitality of the tissues and be a contraindication to particular treatments. Examples are respiratory or cardiac disease, diabetes, rheumatoid arthritis and epilepsy. The prolonged use of **oral steroid** medication should be noted, as this **affects bone density** and produces a tendency towards bruising. This is commonly found in patients suffering **chronic respiratory diseases, inflammatory bowel diseases or rheumatoid arthritis.** Always identify cases of unexplained weight loss and general debility.

N.B Unexplained weight loss, general debility or the patient looking generally unwell – unremitting pain that is unrelieved by changing position or medication – may suggest a non-mechanical basis for the pain. Feeling unwell or tired is common in neoplastic disease affecting the spine. In these cases malignant disease should be suspected and the patient should be referred back immediately to the referring GP or consultant with a full report of your findings Physiotherapy management may well be contraindicated in this situation and may be wasting valuable time for the patient.

Medication

Record the type and dosage of medication prescribed for, or taken by, the patient. Commonly prescribed drugs for use in musculoskeletal conditions are:

- **Analgesics** (painkillers), e.g. paracetamol and co-codamol;
- **non-steroidal anti-inflammatory drugs** (NSAIDs), e.g. **ibuprofen;**
- **Skeletal muscle relaxants**, e.g. diazepam and baclofen**.**

Medications being taken should alert you to pathologies that the patient may have forgotten to inform you about.

For example, a person may tell you that she/he has no significant medical history, but then later in the assessment say that she/he is currently taking anticoagulation therapy for a recent deep vein thrombosis!

Objective Assessment

Following the subjective assessment it is important to highlight the main findings and determine the SIN factor. A hypothesis may be reached as to the cause of the patient's symptoms and the testing procedures are performed in order to support or refute the physiotherapist's hypothesies

Goals of the objective assessment

The objective assessment goals are to seek abnormalities of function, using active, passive, resisted, neurological and special tests of all the tissues involved. This may be guided by the history. However, it is important to conduct all tests objectively and equally, and not attempt to bias the findings in an attempt to make the hypothesis fit.

Objective examination is concerned with performing and recording objective signs. It aims to:

- Reproduce all or parts of the patient's symptoms;
- Determine the pattern, quality, range, resistance and pain response for each movement
- Identify factors that have predisposed or arisen from the disorder
- Obtain signs on which to reassess the effectiveness of treatment by producing reassessment 'asterisks' or 'markers'

General observation

Observe the person’s gait and general demeanour on entering the department.

Gait description

Gait comprises the functions of movement patterns that are associated with walking, running, or other whole-body movements. The gait cycle Kinematics is the study of the movement of the body and body segments with no reference to the forces which may be acting. For instance, during normal walking there is an obvious division in the length of time that the foot is in contact with the ground and the period when it is not. These are known as the ‘stance phase’ (approximately 60% of the gait cycle) and the ‘swing phase’ (approximately 40% of the gait cycle) respectively.

Indications

Tests and measures may be indicated based on the patient/client history, including symptom investigation, or based on the detection of signs by the physical therapist during examination and patient/client management.

Indications for gait tests and measures may include, but are not limited to, the following:

- Complaints of pain with walking or running
- Coordination impairments (eg, balance disorders, ataxia, athetosis)
- Decreases in strength or range of motion
- Impaired endurance
- Inefficient locomotion (speed, endurance, safety)
- Report of falls
- Skeletal alignment or joint impairments
- Skeletal deformity
- Use or need of assistive technology for walking, running, or moving

Tests and Measures

Examples may include, but are not limited to, the following:

- Gait analysis analysis (eg, gait cycle, cadence, stance time, toe off/heel strike, swing time, abnormal postural changes)
- Motion analysis

- Observation of the use of assistive/adaptive devices and orthotic and prosthetic devices
- Observation/qualitative analysis of movement patterns and functions
- Postural analysis
- Technology-assisted mobility analysis systems

Spatial parameters

We can display spatial parameters of foot contact during gait as a series of footprints (Figure 3). These can also be defined as follows:

- ***step length*** – the distance between two consecutive heel strikes;
- ***stride length*** – the distance between two consecutive heel strikes by the same leg;
- **foot angle** or angle of gait – the angle of foot orientation away from the line of progression;
- ***base width or base of gait*** – the medial lateral distance between the centre of each heel during gait.

Temporal parameters

We can display temporal parameters of heel strike and toe off pictorially (Figure 3). These can also be defined as follows:

- ***step time*** – the time between two consecutive heel strikes;
- ***stride time*** – the time between two consecutive heel strikes by the same leg, one complete gait cycle;
- ***single support*** – the time over which the body is supported by only one leg;
- ***double support*** – the time over which the body is supported by both legs;
- ***swing time*** – the time taken for the leg to swing through while the body is in single support on the other leg;
- ***total support*** – the total time a foot is in contact with the ground during one complete gait cycle.

Two other parameters may easily be calculated using this information: **cadence and velocity**. The cadence is the number of steps taken in a given time, usually steps per minute.

- $\text{Cadence (steps/min)} = \dfrac{\textit{Number of steps}}{\textit{Time (min)}}$

Velocity may be calculated by:

- $\text{Velocity (m/s)} = \dfrac{\textit{step length (m)} \times \textit{cadence}\left(\dfrac{\textit{steps}}{\textit{min}}\right)}{60\ (\textit{number of seconds in one minute})}$

Symmetry can also be assessed by dividing the value of a parameter found for the left over that of the right:

- $\text{Symmetry of step length} = \dfrac{\textit{step length for left}}{\textit{step length for right}}$

These parameters, although simple, can be a very useful means of outcome assessment. It must be noted, however, that these may not always be appropriate for some more complex pathological gait patterns For example, the features of ***Parkinsonian gait*** can include a reduction in stride length and velocity, and an increase in base width. However, this results in a characteristic ***shuffling gait*** which makes it hard to determine the events of heel strike and toe off.

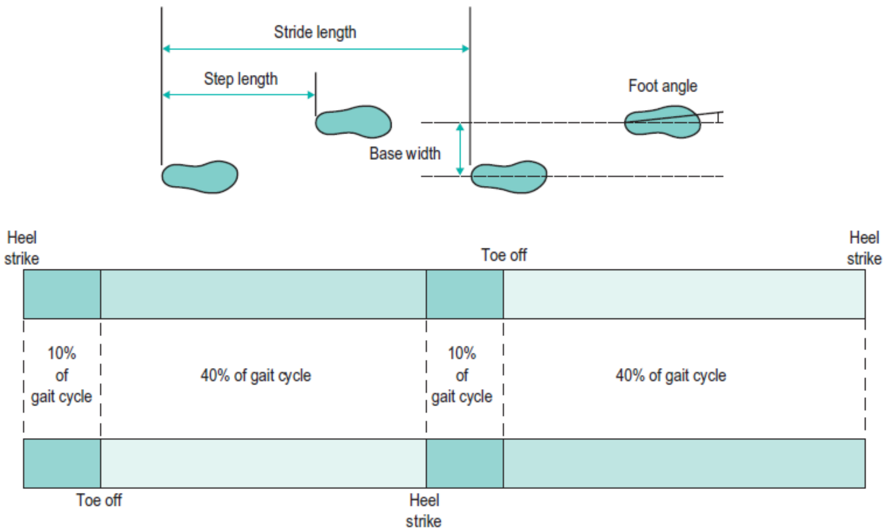
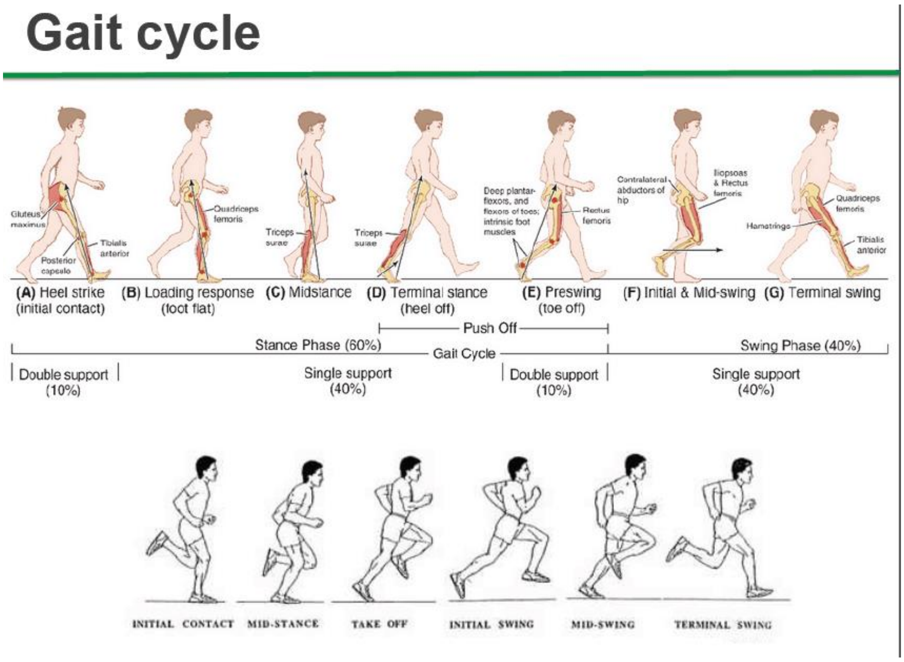


Figure 3 Spatial and temporal parameters.



Gait in the children

1. The walking base is wider
2. The stride length and speed are lower and the cycle time shorter (higher cadence)
3. Small children have no heel strike, initial contact being made by the flat foot
4. There is a little knee flexion during the stance phase
5. The whole leg is externally rotated during the swing phase
6. There is an absence of reciprocal arm swinging Gait in the elderly
7. Two influences:
8. The effects of age itself
9. **The effects of pathological conditions, such as OA and parkinsonism**.

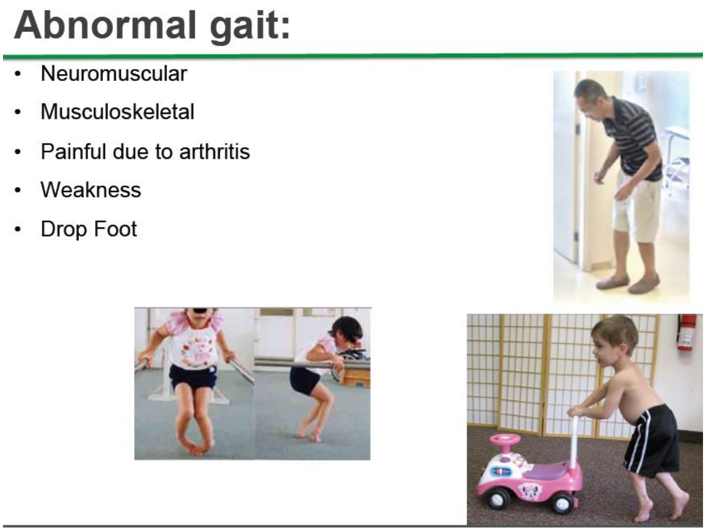
It is characterized by

- Decreased stride length
- Increase the walking base
- Increase the duration of stance phase
- Speed is reduced

Abnormal gait:

Complex interaction between the many neuromuscular and structural elements of the locomotor system. When studying a pathological gait, it is helpful to remember that **an abnormal movement may be performed for one of two reasons:**

1. The subject has no choice, the movement being ‘forced’ on them by weakness, spasticity or deformity
2. The movement is a compensation, which the subject is using to correct for some other problem, which therefore needs to be identified.



Lateral trunk bending (Trendelenburg gait).

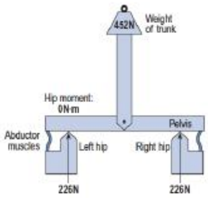


Fig. 3.1 Schematic of double legged stance: the force in each hip joint (226 N) is half the weight of the trunk (452 N). The abductors are not contracting.

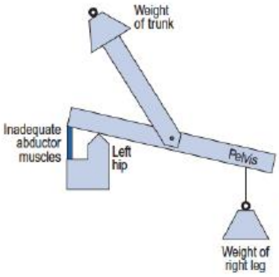
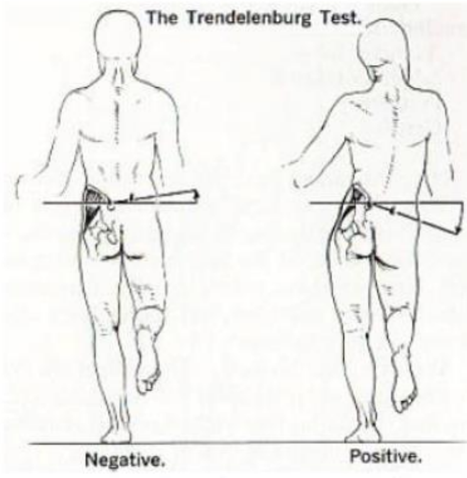


Fig. 3.4 Trendelenburg's sign: due to inadequate hip abductors, the pelvis drops on the unsupported side when one foot is lifted off the ground. To compensate, the subject bends the trunk over the supporting hip.



Trunk bending

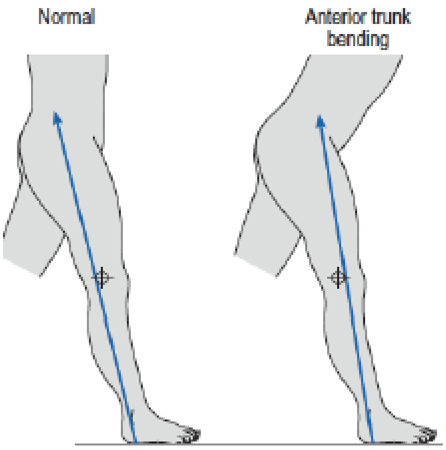


Fig. 3.6 Anterior trunk bending: in normal walking, the line of force early in the stance phase passes behind the knee; anterior trunk bending brings the line of force in front of the knee, to compensate for weak knee extensors.

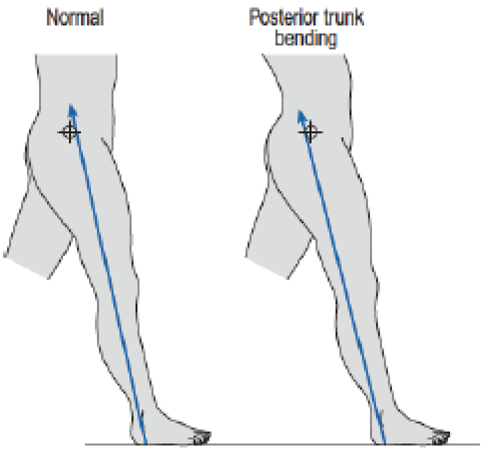


Fig. 3.7 Posterior trunk bending: in normal walking, the line of force early in the stance phase passes in front of the hip; posterior trunk bending brings the line of force behind the hip, to compensate for weak hip extensors.

Excessive knee Flexion

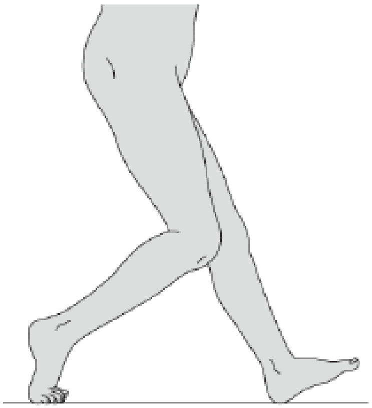


Fig. 3.14 Excessive knee flexion: in late stance phase there is increased knee flexion, caused by a flexion contracture of the hip.

Gait Deviations	Reasons
Slower cadence than expected for person's age	Generalized weakness Pain Joint motion restrictions Poor voluntary motor control/weakness of lower limb muscles
Shorter stance phase on involved side and decreased swing phase on uninvolved side Shorter stride length on uninvolved side Decrease lateral sway over involved stance limb Decrease in velocity	Antalgic gait, resulting from painful injury to lower limb and pelvic region
Stance phase longer on one side	Pain Lack of trunk and pelvic rotation Restrictions in lower limb joints Increased muscle tone
Lateral trunk lean (purpose is to bring center of gravity of trunk nearer to hip joint)	Ipsilateral lean (toward the stance leg)—marked hip abductor weakness (compensated gluteus medius/Trendelenburg gait) Contralateral lean—decreased hip flexion in swing limb—mild hip abductor weakness (gluteus medius/Trendelenburg gait) Painful hip Abnormal hip joint (congenital dysplasia, coxa vara, etc.) Wide walking base Unequal leg length Adaptive shortening of quadratus lumborum on swing side Contralateral hip adductor spasticity
Anterior trunk leaning at initial contact (occurs to move line of gravity in front of axis of knee)	Weak or paralyzed knee extensors or gluteus maximus Hip pain
Anterior trunk leaning during mid and terminal stance, as the hip is moved over the foot	Hip flexion contracture Pes equinus deformity

Posterior trunk leaning during initial contact to loading response (occurs to bring line of external force behind axis of hip)	Weak or paralyzed hip extensors, especially gluteus maximus (gluteus maximus gait) Hip pain Hip flexion contracture Inadequate hip flexion in swing Decreased knee range of motion
Increased lumbar lordosis in terminal stance	Inability to extend hip, usually due to hip flexion contracture or ankylosis
Excessive posterior horizontal pelvic rotation	Adaptively shortened/spasticity of hip flexors on same side Limited hip joint flexion
Hip circumduction during swing (ground contact can be avoided by swinging leg if it is swung outward for natural walking to occur; leg that is in its stance phase needs to be longer than leg that is in its swing phase to allow toe clearance of swing foot)	Functional leg-length discrepancy(shortening of the swing leg secondary to reduced hip flexion, reduced knee flexion, and/or lack of ankle dorsiflexion) Arthrogenic stiff hip or knee
Hip hiking (pelvis is lifted on side of swinging leg, by contraction of spinal muscles and lateral abdominal wall)	Functional leg-length discrepancy (shortening of the swing leg secondary to reduced hip flexion, reduced knee flexion, and/or lack of ankle dorsiflexion) Functionally or anatomically short-stance leg Hamstring weakness Quadratus lumborum shortening
Vaulting (ground clearance of swinging leg will be increased if the patient goes up on toes of stance phase leg)	Functional leg-length discrepancy Vaulting occurs on shorter limb side

Gait Deviations	Reasons
Abnormal internal hip rotation (produces "toe-in" gait)	Adaptive shortening of iliotibial band Weakness of hip external rotators Femoral anteversion Adaptive shortening of hip internal rotators
Abnormal external hip rotation (produces "toe-out" gait)	Adaptive shortening of hip external rotators Femoral retroversion Weakness of hip internal rotators
Increased hip adduction (scissors gait), which results in excessive hip adduction during swing (scissoring), decreased base of support, and decreased progression of opposite foot Inadequate hip extension/excessive hip flexion, which results in loss of hip extension in midstance (forward leaning of trunk, increased lordosis, and increased knee flexion and ankle dorsiflexion) and late stance (anterior pelvic tilt), and increased hip flexion in swing	Spasticity or contracture of ipsilateral hip adductors Ipsilateral hip adductor weakness Coxa vara Hip flexion contracture Iliotibial band contracture Hip flexor spasticity Pain Arthrodesis (surgical or spontaneous ankylosis) Loss of ankle dorsiflexion
Inadequate hip flexion, which results in decreased limb advancement in swing, posterior pelvic tilt, circumduction, and excessive knee flexion to clear foot	Hip flexor weakness Hip joint arthrodesis
Decreased hip swing through (psoatic limp), which is manifested by exaggerated movements at pelvis and trunk to assist hip to move into flexion	Legg–Calvé–Perthes disease Weakness or reflex inhibition of psoas major muscle
Excessive knee extension/inadequate knee flexion, which results in decreased knee flexion at initial contact and loading response, increased knee extension during stance, and decreased knee flexion during swing	Pain Anterior trunk deviation/bending Weakness of quadriceps; hyperextension is a compensation and places body weight vector anterior to knee Spasticity of the quadriceps; noted more during the loading response and during initial swing intervals Joint deformity

Excessive hip and knee flexion during swing	Lack of ankle dorsiflexion of the swing leg Functionally or anatomically short contralateral stance leg
Excessive knee flexion/inadequate knee extension at initial contact or around midstance; results in increased knee flexion in early stance, decreased knee extension in midstance and terminal stance, and decreased knee extension during swing	Knee flexion contracture, resulting in decreased step length and decreased knee extension in stance Increased tone/spasticity of hamstrings or hip flexors Decreased range of motion of ankle dorsiflexion in swing phase Weakness of plantar flexors, resulting in increased dorsiflexion in stance Lengthened limb
Inadequate dorsiflexion control ("foot slap") during initial contact to midstance. Steppage gait during the acceleration through deceleration of the swing phase. The exaggerated knee and hip flexion are used to lift foot higher than usual, for increased ground clearance resulting from foot drop	Weak or paralyzed dorsiflexors Lack of lower limb proprioception Weak or paralyzed dorsiflexor muscles Functional leg-length discrepancy
Increased walking base/step width (>20 cm)	Deformity such as hip abductor muscle contracture Genu valgus Fear of losing balance Leg-length discrepancy
Decreased walking base/step width (<10 cm)	Hip adductor muscle contracture Genu varum

Gait Deviations	**Reasons**
Excessive eversion of calcaneus during initial contact through midstance	Excessive tibia vara (refers to frontal plane position of the distal one-third of leg, as it relates to supporting surface) Forefoot varus Weakness of tibialis posterior Excessive lower extremity internal rotation (due to muscle imbalances and femoral anteversion)
Excessive pronation during midstance through terminal stance	Insufficient ankle dorsiflexion (<10 degrees) Increased tibial varum Compensated forefoot or rearfoot varus deformity Uncompensated forefoot valgus deformity Pes planus Long limb Uncompensated medial rotation of tibia or femur Weak tibialis anterior
Excessive inversion and plantar flexion of the foot and ankle during swing and at initial contact	Pes equinovarus (spasticity of the plantar flexors and invertors)
Excessive supination during initial contact through midstance	Limited calcaneal eversion Rigid forefoot valgus Pes cavus Uncompensated lateral rotation of tibia or femur Short limb Plantar flexed first ray Upper motor neuron muscle imbalance
Excessive dorsiflexion during initial contact through toe-off	Compensation for knee flexion contracture Inadequate plantar flexor strength Adaptive shortening of dorsiflexors Increased muscle tone of dorsiflexors Pes calcaneus deformity
Excessive plantar flexion during midstance through toe-off	Increased plantar flexor activity Plantar flexor contracture
Excessive varus during initial contact through toe-off	Contracture Overactivity of muscles on medial aspect of foot
Excessive valgus during initial contact through toe-off	Weak invertors Foot hypermobility
Decreased or absence of propulsion (plantar flexor gait) during mid-stance through toe-off	Inability of plantar flexors to perform function, resulting in a shorter step length on the involved side

Some Causes of Antalgic Gait

Cause	Examples
Bone disease	Fracture Infection Tumor Avascular necrosis (Legg–Calvé–Perthes disease, Osgood Schlatter disease, and Köhler bone disease)
Muscle disorder	Traumatic rupture and contusion Cramp secondary to fatigue, strain, malposition, or claudication Inflammatory myositis
Joint disease	Traumatic arthritis Infectious arthritis Rheumatoid arthritis Crystalline arthritis (gout and pseudogout) Hemarthrosis Bursitis
Neurologic disease	Lumbar spine disease with nerve root irritation or compression
Other	Hip, knee, or foot trauma Corns, bunions, blisters, or ingrown toenails

Gait Abnormalities in Arthritic Disease and Associated Conditions and Treatment Examples

	Gait Abnormalities				
Disorder	Observational	Time–Distance	Angular	Kinetic and EMG	Treatment
Osteoarthritis of the hip, unilateral involvement	Lateral lurch gait pattern	1. ↑ Stance time, uninvolved side 2. ↑ Double-limb support 3. ↑ Step time, involved side 4. ↓ Step length, involved side 5. ↓ Velocity	↓ Hip flexion–extension excursion, involved side	↓ Hip abductor moment	Assistive device (cane or crutches)
Rheumatoid arthritis with hindfoot pain and deformity	1. Antalgic gait pattern 2. Flat-foot gait pattern	1. ↓ Velocity 2. ↓ Single-limb support, involved side 3. ↓ Cadence 4. ↓ Stride length 5. Delayed heel rise	1. ↑ Knee flexion during stance 2. ↑ Dorsiflexion during stance 3. ↓ Plantar flexion during terminal stance 4. ↑ Subtalar eversion during terminal stance	↑ Tibialis anterior activation during terminal stance and preswing	Cane Rigid AFO or hindfoot orthoses Rocker bottom shoes
Total knee arthroplasty, unilateral		1. ↓ Single-limb support, involved side 2. ↓ Stride length	↓ Knee flexion during stance	↓ Knee extensor moment	N/A

Gait Abnormalities Associated with Muscle Weakness and Treatment Examples

Disorder	Gait Abnormalities				Treatment
	Observational	Time–Distance	Angular	Kinetic and EMG	
Dorsiflexor paresis or paralysis	1. Steppage gait pattern 2. Foot slap gait pattern	1. ↓ Time to foot flat 2. ↓ Step length	1. Ankle plantar flexion during swing 2. ↑ Hip and knee flexion during swing	↓ Dorsiflexor moment	AFO
Hip abductor weakness	1. Trendelenberg gait pattern 2. Lateral lurch gait pattern	1. ↑ Double-limb support 2. ↓ Step length 3. ↓ Velocity	1. ↑ Hip adduction during midstance, with Trendelenberg 2. ↑ Lateral trunk tilt with lateral lurch 3. ↓ Pelvic tilt during swing, involved side, with Trendelenberg	Hip abductor ↓ moment during stance with lateral lurch	Assistive device (cane and crutches)
Plantar flexor paresis or paralysis	No pattern discernible	1. Prolonged midstance 2. ↓ Step length, uninvolved side 3. ↓ Single-limb support, involved side	1. ↑ Stance phase knee flexion 2. ↑ Stance phase dorsiflexion	1. ↓ Plantar flexor power during late stance. 2. Prolonged stance phase quadriceps activation	AFO

Gait Abnormalities Associated with Neurologic Disorders and Treatment Examples

Disorder	Gait Abnormalities: Observational	Time–Distance	Angular	Kinetic and EMG	Treatment
Ataxia	"Ataxic" gait pattern	Variable stride to stride	Variable stride to stride	Variable stride to stride	1. Orthotic stabilization to control movement variability 2. Walking aids (e.g., crutches and walker)
Hemiplegia from stroke	1. "Stiff-legged" gait pattern 2. Equinus or equinovarus gait pattern 3. Circumduction	1. ↑ Double-limb support 2. ↓ Step length, involved side 3. Delayed heel rise 4. ↓ Velocity 5. ↓ Stride length 6. ↓ Cadence 7. Absent heel contact 8. Toe drag during swing	1. ↑ Plantar flexion during swing 2. ↓ Knee flexion during stance and swing	1. ↑ Knee flexor moment during stance 2. ↓ Amplitude of joint powers 3. Abnormal timing of muscle activation (i.e., mass synergy patterns)	1. Ankle–foot orthosis 2. Rectus femoris release 3. Tendo-Achilles lengthening 4. Tendon transfer, foot and ankle 5. Functional electrical stimulation
Parkinson disease	1. "Shuffling" gait pattern 2. "Frozen" gait pattern	1. ↓ Stride length 2. ↓ Step length 3. ↓ Step width 4. ↓ Cadence 5. ↓ Velocity	↓ Angular excursions throughout	Agonist–antagonist coactivation with "frozen" pattern	Pharmaceutical/medical management

Local observation Abnormalities Associated with Muscle Weakness and Treatment Examples Note any **localized swelling** at the joint. This may be measured with a tape measure around the joint or limb circumference. Note any asymmetry of joint contours, redness of the overlying skin suggesting local inflammation, **atrophy and asymmetry of musculature, deformity, and malalignment of the joint or joints**. **Compare** one joint closely with the other side whenever possible

Posture

Observe any asymmetry of posture in standing, walking and sitting. Poor posture is frequently a precursor to muscle imbalance, selective tightness and weakness through over- or under-use of specific muscles. The result of prolonged poor postural habits may lead to acceleration of certain pathologies such as adhesive capsulitis shoulder impingement syndrome, spinal pain and arthritis. Poor posture is frequently the cause of aches and pains and may be correctable in the early stages and improved in later stages. Correction may prevent recurrence or acceleration of specific pathologies

Palpation

Palpate for the following:

- Tenderness;
- heat (use the back of your hand – it is more sensitive to heat changes);
- swelling;
- Muscle spasm.

Assessment of movement

Active movements

These are movements performed by the patient's voluntary muscular effort.

Passive movements

These are movements performed by an external source, such as the physiotherapist or a pulley system. There are two types of passive movements.

- **Physiological movements** are movements that could be performed actively by the patient (e.g. flexion of the knee or abduction of the shoulder joint)
- **Accessory movements** cannot be performed actively by the patient (e.g. they incorporate glide, roll or spin movements that occur in combination as part of normal physiological movements). An example of an accessory movement is an anterior–posterior gliding at the knee joint.

Resisted movements

These are performed against the resistance of the physiotherapist or weights by the patient's own effort.

N.B: Passive, active and resisted movements are used in the assessment and in the treatment of musculoskeletal disorders. Specific examples of these are included later in the individual joint assessments formats.

Assessment of range of movement

Measurement of joint range using a goniometer

Active movement may be assessed by the use of a goniometer (Figure.3) or, alternatively, by visual estimation. It is measured in degrees and it is useful to practise using the goniometer by measuring the hip, knee and ankle joints in various positions. Either the 360 or 180° universal goniometers may be used. Ensure adequate stabilization of adjacent joints prior to taking the measurements and locate the appropriate anatomical landmarks as accurately as possible. For details on specific joint measurements using the goniometer, refer to the appropriate joint assessment.

Physiological and accessory passive movements are measured in terms of the above and by the end-feel respectively.

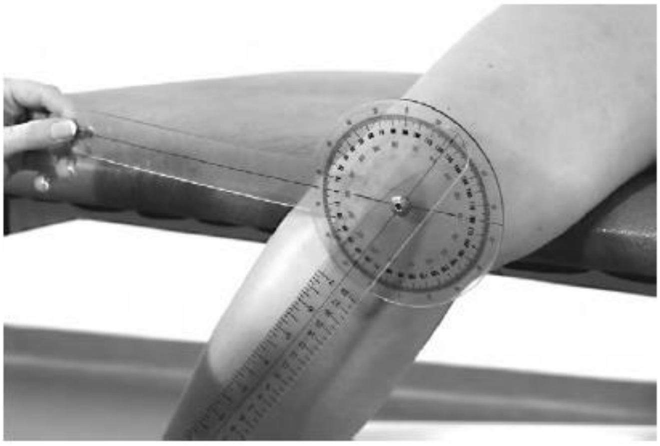


Figure 3 Using the goniometer to measure hip joint medial rotation with the hip in 90 degrees of flexion.

Differentiation tests

If a lesion is situated within a non-contractile structure such as ligament, then both the active and passive movements will be painful and/or restricted in the same direction. For example, both the active and passive movement of inversion will produce pain in the case of a sprained lateral ankle ligament. However, if a lesion is within a contractile tissue such as a muscle, then the active and passive movements will be painful and/or restricted in opposite directions. For example, a ruptured quadriceps muscle will be painful on passive knee flexion (stretch) and resisted knee extension (contraction).

N.B Remember that it is insufficient to measure only the range of movement occurring. The quality of movement should also be observed, along with limiting factors to the movement. Is it the pain, muscle spasm, weakness or stiffness that is limiting the movement? This is determined by noting the differences between active, passive and resisted movements.

End-feel

During passive movements, the end-feel is noted. Different joints and different pathologies have different end feels.

The quality of the resistance felt at the end of range has been categorised by Cyriax .For example:

- **bony block** to movement or a hard feel ischaracteristic of arthritic joint
- **an empty feel**, or no resistance offered at the end of range, may be a result of severe pain associated with infection, active inflammation or a tumour;
- **a springy block** is characterised by a rebound feel at the end of range and is associated with a torn meniscus blocking knee extension;
- **spasm** is experienced as a sudden, relatively hard feel associated with muscle guarding;
- **a capsular feel** shows a hardish arrest of movement.

Assessment of muscle strength

Symptoms arising from resisted contractions

The Oxford scale is relatively quick and easy to use, and is used widely in clinical practice. However, it is not very objective, functional or sensitive to change as the movements resisted are concentric contractions and the spaces between the grades are not linear. Nevertheless, it provided a guide to muscle strength and is somewhat sensitive to change.

The Oxford classification

0 = no contraction at all

1 = flicker of contraction only, movement of the joint does not occur

2 = movement is possible only with gravity counterbalanced

3 = movement against gravity is possible

4 = movement against resistance is possible

5 = normal functional movement is possible

Measurements using isokinetic machines

Objective measurements of strength throughout different joint angles and at different velocities are made more accurately using isokinetic machines, such as **Cybex or Kin- Kom**. These machines are particularly valuable in rehabilitative regimens such as anterior cruciate rehabilitation programmes and can determine the strength ratio of the quadriceps to the hamstrings, or the ratios of the operated versus the non-operated leg. Objective markers such as percentages of strength ratios or ratios of operated versus non-operated leg may be used in setting discharge protocols. **Isokinetic machines** have been found to be reliable and valid in measuring muscle torque, muscle velocity and the angular position of joints. However, they are limited in their use, and some researchers suggest that agility and functional exercises may be more beneficial than isokinetic machines in the strengthening of muscle.

N.B Tests of specific structures are performed in order to reproduce the patient's symptoms or signs, i.e. to reproduce the comparable sign. Differentiation tests are useful to distinguish between two or more structure that are suspected to be the source of the symptoms.

Differentiation tests of muscles and tendons

These are contractile structures and are therefore tested by performing a contraction against resistance. A pain response and/or apparent weakness may indicate a strain of the muscle at any particular point of the range of movement. Full range should be checked as the muscle may be weak only at a particular point in the range. Muscle length may also be tested, particularly those muscles that are prone to become tight and then lose their extensibility Muscles that pass over two joints and have mobiliser characteristics are particularly prone to tightness. Examples of these are the hamstrings, rectus femoris, gastrocnemius and psoas major. The length of the muscle is tested by passively moving the appropriate joints. The stretch is compared with the other side to determine reproduction of pain and/or restriction of movement.

Passive insufficiency of muscles

This occurs with muscles that act over two joints (Figure4a). The muscle cannot stretch maximally across both joints at the same time. For example, **the hamstrings** may limit the flexion of the hip when the knee joint is in extension as they are maximally stretched in this position However, if the knee is flexed passively, then the hip will be able to flex further as the stretch on the hamstrings has been reduced.

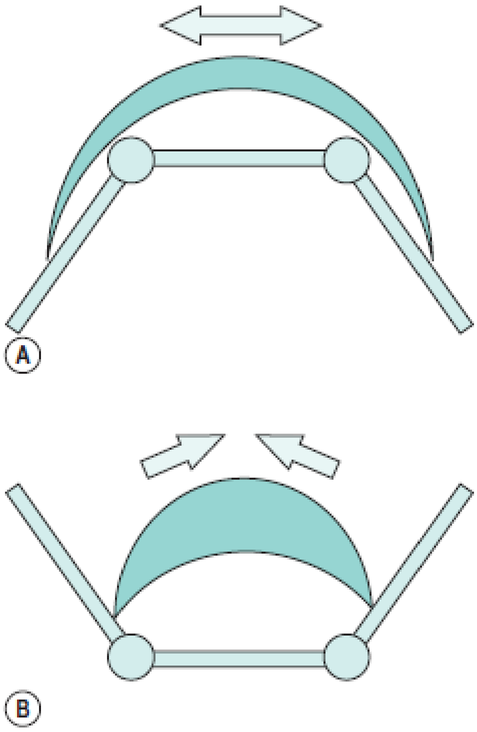


Figure 4 (a) Passive insufficiency: the muscle cannot

Simultaneously stretch maximally across two joints. (b) Active insufficiency. The muscle cannot simultaneously contract maximally across two joints.

Active insufficiency of muscles

This, too, occurs with muscles that act over two joints (Figure 4b). The muscle cannot contract maximally across both joints at the same time. An example is the finger flexors. If you are to make a strong fist, you may notice that the wrist is in a neutral or an extended position when you do this action. Now, **if you attempt to actively flex your wrist joint whilst keeping your fingers flexed, you will find that the strength of the grip is greatly diminished**.

This is because the wrist and finger flexors are unable to shorten any further and so the fingers begin to extend or lose grip strength.

Differentiation tests of ligaments

Ligaments are non-contractile structures and are tested by putting the structure on stretch. Examples are a **valgus strain** of the knee to stretch the medial collateral ligament of the knee or passive inversion of the subtalar joint to stretch the lateral ligament of the ankle. A positive test would be a pain response or observation or feel of any excessive movement of the joint when compared with the other side.

Differentiation tests of bursae

Bursae are sacs of synovial fluid. Inflammation of these (bursitis) results in tenderness and/or heat on palpation.

The tenderness is often very localised to the site of the inflamed bursa.

Differentiation tests of menisci

The history and mechanism of injury combined with anterior joint tenderness and the inability to passively hyperextend the knee are useful diagnostic markers of meniscal injury. Rotation on a semi-flexed weight-bearing knee is a common cause of injury. **A history of locking**, whereby the joint momentarily locks and is unable to actively or passively release itself from the position, is also common. Objectively, the knee joint is unable to fully flex/hyperextend passively

Characteristics of degenerative joint disease

Signs and symptoms may include:

- Pain that increases on weight-bearing activities (standing and walking, walking downstairs particularly
- insidious onset of symptoms followed by progressive periods of relapses and remissions.
- pain and stiffness in the morning.
- Stiffness following periods of inactivity.
- pain and stiffness that arise after unaccustomed periods of activity.
- bony deformity (e.g. characteristic varus deformity may follow from collapse of the medial compartmental joint space
- reduction of the joint space observed on X-ray, with bony outgrowths or osteophytes.

Neurological testing

Compression or traction of spinal nerve roots by disc and/or osteophytes may give rise to referred pain, paraesthesia and anesthesia, and also give positive neurological signs. Neurological signs should be carefully monitored as deterioration may indicate worsening pathology.

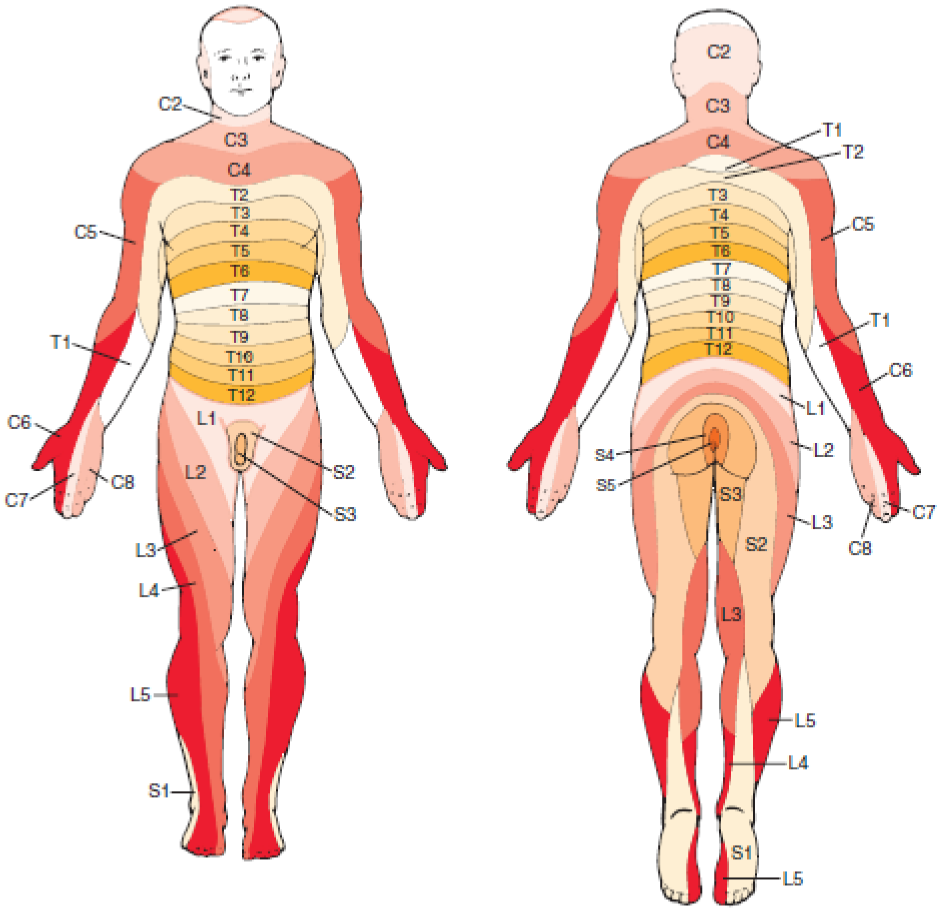
Dermatomes

A dermatome is an area of skin supplied by a particular spinal nerve. Dermatomes may exhibit sensory changes for light touch and pin prick. Test each dermatome individually, on the unaffected and then the affected side.

Cervical dermatomes (C2-C8, as C1 nerve has no dermatome) - The "C" stands for cervical, which means having to do with any part of the neck, including the neck on which the head is perched, and the neck of the uterus **(Figure 5)**.

- C2 - At least one cm lateral to the occipital protuberance at the base of the skull. Alternately, a point at least 3 cm behind the ear.
- C3 - In the supraclavicular fossa, at the midclavicular line.
- C4 - Over the acromioclavicular joint.
- C5 - On the lateral (radial) side of the antecubital fossa, just proximally to the elbow.
- C6 - On the dorsal surface of the proximal phalanx of the thumb.
- C7 - On the dorsal surface of the proximal phalanx of the middle finger.
- C8 - On the dorsal surface of the proximal phalanx of the little finger.
- T1 - On the medial (ulnar) side of the antecubital fossa, just proximally to the medial epicondyle of the humerus.
- T2 - At the apex of the axilla.
- T3 - Intersection of the midclavicular line and the third intercostal space
- T4 - Intersection of the midclavicular line and the fourth intercostal space, located at the level of the nipples.
- T5 - Intersection of the midclavicular line and the fifth intercostal space, horizontally located midway between the level of the nipples and the level of the xiphoid process.

- T6 - Intersection of the midclavicular line and the horizontal level of the xiphoid process.
- T7 - Intersection of the midclavicular line and the horizontal level at one quarter the distance between the level of the xiphoid process and the level of the umbilicus.
- T8 - Intersection of the midclavicular line and the horizontal level at one half the distance between the level of the xiphoid process and the level of the umbilicus.
- T9 - Intersection of the midclavicular line and the horizontal level at three quarters of the distance between the level of the xiphoid process and the level of the umbilicus.
- T10 - Intersection of the midclavicular line, at the horizontal level of the umbilicus.
- T11 - Intersection of the midclavicular line, at the horizontal level midway between the level of the umbilicus and the inguinal ligament.
- T12 - Intersection of the midclavicular line and the midpoint of the inguinal ligament.
- L1 - Midway between the key sensory points for T12 and L2.
- L2 - On the anterior medial thigh, at the midpoint of a line connecting the midpoint of the inguinal ligament and the medial epicondyle of the femur.
- L3 - At the medial epicondyle of the femur.
- L4 - Over the medial malleolus.
- L5 - On the dorsum of the foot at the third metatarsophalangeal joint.
- S1 - On the lateral aspect of the calcaneus.
- S2 - At the midpoint of the popliteal fossa.
- S3 - Over the tuberosity of the ischium or infragluteal fold
- S4 and S5 - In the perianal area, less than one cm lateral to the mucocutaneous zone



(Figure 5).Dermatome

Sensory System

The Sensory System Examination

The sensory exam includes testing for: **pain sensation (pin prick), light touch sensation (brush), position sense, stereognosia, graphesthesia, and extinction**. Diabetes mellitus, thiamine deficiency and neurotoxin damage (e.g. insecticides) are the most common causes of sensory disturbances. The affected patient usually reports paresthesias (pins and needles sensation) in the hands and feet. Some patients may report dysesthesias (pain) and sensory loss in the affected limbs also.

Pain and Light Touch Sensation

Initial evaluation of the sensory system is completed with the patient lying supine, eyes closed. Instruct the patient to say "sharp" or "dull" when they feel the respective object. Show the patient each object and allow them to touch the needle and brush prior to beginning to alleviate any fear of being hurt during the examination.

With the patient's eyes closed, alternate touching the patient with the needle and the brush at intervals of roughly 5 seconds. Begin rostrally and work towards the feet.

Make certain to instruct the patient to tell the physician if they notice a difference in the strength of sensation on each side of their body.

Alternating between pinprick and light touch, touch the patient in the following 13 places. Touch one body part followed by the corresponding body part on the other side (e.g., the right shoulder then the left shoulder) with the same instrument. This allows the patient to compare the sensations and note asymmetry. (Fig 6)

(Fig 6) pinprick

If there is a sensory loss present, **test vibration sensation** and **temperature sensation** with the tuning fork. Also concentrate the sensory exam in the area of deficiency.

(Fig 7) Position Sense

Position Sense

Test position sense by having the patient, eyes closed, report if their large toe is "up" or "down" when the examiner manually moves the patient's toe in the respective direction. Repeat on the opposite foot and compare. Make certain to hold the toe on its sides, because holding the top or bottom provides the patient with pressure cues which make this test invalid. (Fig 7)

Fine touch, position sense (proprioception) and vibration sense are conducted together in the **dorsal column system.** Rough touch, temperature and pain sensation are conducted via the **spinothalamic tract**. Loss of one modality in a conduction system is often associated with the loss of the other modalities conducted by the same tract in the affected area.

(Fig 8) Stereognosia

Stereognosia

Test stereognosis by asking the patient to close their eyes and identify the object you place in their hand. Place a coin or pen in their hand. Repeat this with the other hand using a different object. **(Fig 8)**

Astereognosis refers to the inability to recognize objects placed in the hand. Without a corresponding dorsal column system lesion, these abnormalities suggest a lesion in the sensory cortex of the parietal lobe

(Fig 9) Graphesthesia

Graphesthesia

Test graphesthesia by asking the patient to close their eyes and identify the number or letter you will write with the back of a pen on their palm. Repeat on the other hand with a different letter or number. **(Fig 9)**

Apraxias are problems with executing movements despite intact strength, coordination, position sense and comprehension. This finding is a defect in higher intellectual functioning and is associated with cortical damage.

Extinction

To test extinction, have the patient sit on the edge of the examining table and close their eyes. Touch the patient on the trunk or legs in one place and then tell the patient to open their eyes and point to the location where they noted sensation. Repeat this maneuver a second time, touching the patient in two places on opposite sides of their body, simultaneously. Then ask the patient to point to where they felt sensation. Normally they will point to both areas. If not, extinction is present. **(Fig 10)**

(Fig 10) Extinction

With lesions of the sensory cortex in the parietal lobe, the patient may only report feeling one finger touch their body, when in fact they were touched twice on opposite sides of their body, simultaneously. With extinction, the stimulus not felt is on the side opposite of the damaged cortex. The sensation not felt is considered "extinguished".

Myotomes

A myotome is a muscle supplied by a particular nerve root level. These are assessed by performing isometric resisted tests of the myotomes L1–S1 in middle range, held for approximately three seconds. Test the unaffected side, then the affected as follows:

- C1/C2f for neck flexion/extension
- C3 for neck lateral flexion

- C4 for shoulder elevation
- C5 for shoulder abduction
- C6 for elbow flexion/wrist extension
- C7 for elbow extension/wrist flexion/finger extension
- C8 for finger flexion
- T1 for finger abduction
- LI–L2 for the hip flexors
- L3–L4 for knee extensors
- L4 for foot dorsiflexors and invertors,
- L5 for extension of the big toe,
- S1 for plantar flexion and knee flexion,
- S2 for knee flexion and toe standing
- S3–S4 for muscles of the pelvic floor and the bladder

Reflexes

- Test the non-affected first then affected side. Note: dull reflexes may indicate lower motor neurone dysfunction. Brisk reflexes may indicate an upper motor neurone dysfunction.
- C5–C6 correspond to biceps brachii. The person's arm should be semi-flexed at the elbow with the forearm pronated. Place your thumb or finger firmly on the biceps tendon and hit your finger with the hammer (Figure 11).

Figure 11. The biceps reflex (C5, C6).

- C6–C8 correspond to triceps. Support the person's upper arm and let the forearm hang free. Hit the triceps tendon above the elbow (Figure 12).

Figure 12 The triceps reflex (C6, C7).

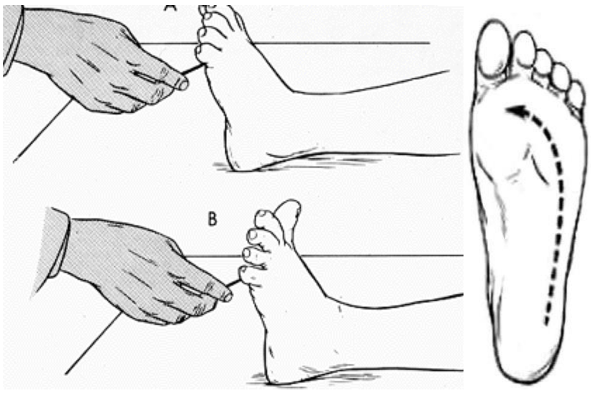
- L3 corresponds to the quadriceps. The patient sits with the knee flexed and the therapist hits the patellar tendon just below the patella (Figure 13)

Figure 13 The quadriceps reflex (L2, L3, L4).

- S1 corresponds to the plantarflexors. Dorsiflex the ankle and strike the Achilles tendon. Observe and feel for plantar flexion at the ankle (Figure 14).

Figure 14 The Achilles tendon reflex (S1, S2).

The Babinski reflex (or plantar response) is an abnormal response and occurs when a blunt object is drawn up the lateral aspect of the sole of the foot. Normally, the great toe (big toe) flexes. Abnormally, the great toe extends indicating upper motor neuron damage. Note that this primitive reflex is seen in the newborn but disappears with time (figure 15).



(figure 15).A) normal response B) abmormal response The Babinski reflex

Adverse mechanical tension

Passive neck flexion

The patient is supine. The physiotherapist flexes the patient’s neck passively. Observe for any low back pain response, which may suggest disc pathology.

Straight leg raise (SLR)

This is also known as Lasegue’s test. The patient is supine. The physiotherapist lifts the patient’s leg while maintaining extension of the knee (Figure 16). An abnormal finding is back pain or sciatic pain. The sciatic nerve is on full stretch at approximately 70 degrees of flexion, so a positive sign of sciatic nerve involvement occurs before this point. Any pain response and range of movement is noted and comparison made with the other side. Factors such as hip adduction and medial rotation further sensitise the sciatic nerve; dorsiflexion of the ankle will sensitise the tibial portion of the sciatic nerve; plantar flexion and inversion will sensitise the peroneal portion of the nerve.

(Figure 16) SLR test adding dorsiflexion of the ankle joint.

Prone knee bend (femoral nerve stretch)

The patient lies prone and the physiotherapist flexes the person’s knee and then extends the hip (Figure 17) Pain in the back or distribution of the femoral nerve indicate femoral nerve irritation or reduced mobility. Comparison is made with the other side

Figure17 Femoral nerve test

Slump test

This tests the mobility of the dura mater. The patient sits with thighs fully supported with hands clasped behind the back. The patient is instructed to slump the shoulder towards the groin (Figure 18). The physiotherapist applies gentle overpressure to this trunk flexion. The patient adds cervical flexion, which is maintained by the therapist. The patient then performs unilateral active knee extension and active ankle dorsiflexion. The physiotherapist should not force the movement. The non-affected side should be assessed first. Any symptoms are noted at the particular part in range. If the dura mater is tethered, symptoms will increase as each component is added to the slump test. The patient is instructed to extend the head – a reduction in symptoms on cervical extension is a positive finding, indicating abnormal neurodynamics.)

Figure 18 Slump test with single knee extension.

The upper limb tension test (ULTT) is referred to as the SLR test of the cervical spine. This test mobilises the brachial plexus and particularly biases the median nerve to determine the degree to which neural tissue is responsible for producing the patient's symptoms. Certain movementsof the arm, shoulder, elbow, wrist and hand, and, similarly, the neck and the lower limb, can cause neural movement in the cervical spine. These tests are so importan that all physiotherapists should know and use them.

The physiotherapist depresses the patient's shoulder, then adds in 90 degrees abduction, 90 degrees lateral rotation of the shoulder, elbow extension, forearm supination, and wrist and finger extension to the supine patient (Figure 19. a). Sensitising manoeuvres such as ipsilateral (same side) or contralateral (opposite side) cervical rotation and side flexion are added (Figure 19. b). Symptoms of pain, paraesthesia and restriction are noted and compared with the other side. Common findings will be reduced range or the reproduction of symptoms on the affected side.

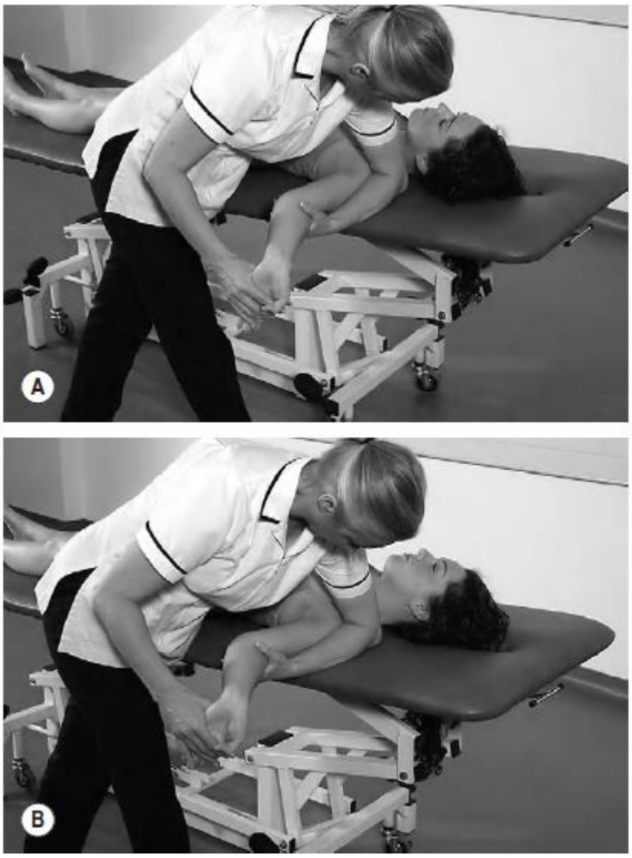


Figure 19 (a) Upper limb tension test (ULTT). (b) ULTT with contralateral right side flexion of the cervical spine.

Writing up the assessment

It is imperative to record the assessment immediately following the physical testing. Patient notes should be completed on the day of the assessment for legal reasons. Ensure that your assessment findings are clear and concise, and that they highlight the main points (it may be useful to include one subjective and one objective marker). Formulate a problem list in agreement with the patient. Agree and record **SMART goals (specific, measurable, achievable, realistic, timed)** with the patient. Use the problem-orientated medical records (POMR) system. Remember, if you have insufficient time to conduct full and thorough assessment you can always continue with this when the patient attends for his/her subsequent appointment.

Management of fracture

The principles of fracture management are

1- Reduction of fracture

2-Immobilization of the fracture fragment long enough to allow union

3-Rehabilitation of the soft tissues and joints

Once a fracture has been diagnosed, the most suitable treatment must be decided upon. This should be the minimum possible intervention that will safely and effectively provide the right environment for healing of the fracture. Interestingly, nature has devised a system by which a slight amount of movement at a fracture site is useful in stimulating callus formation so there is a balance to be made between immobilising a fracture but allowing enough movement to stimulate callus formation and healing (Figure 1). This is a common dilemma in orthopaedics. In the same way that there is no recipe for the physiotherapy treatment of a fracture, there is no single recipe for the surgical management of fractures.

.

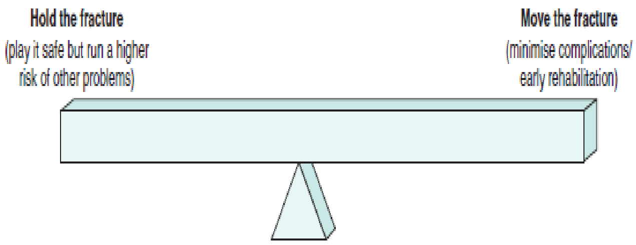


Figure 1 The mobilisation see-saw.

Reduction

Reduction means to realign into the normal position or as near to the normal anatomical position as possible (Figure 2). Reduction of a fracture may be either open or closed. *Closed reduction* means that no surgical ntervention is used with the fracture being manipulated by hand under local or general anaesthesia. *Open reduction* means that the area has been surgically opened and reduced. Reduction may not always be necessary, even when there is some displacement. For example, fractures of the clavicle may heal with a bump which may be a problem only in the cosmetic sense; function is the most important end-point. However, when there is poor alignment of the fragments or the relative positions of the joints above and below the fracture are lost as a result of angulation or rotation of the bone ends, or if there is loss of leg length, then accurate anatomical reduction is necessary. X-rays are used to ascertain the exact position of the fragments before and after reduction. Real-time X-rays can now be taken using image intensifiers so that the surgeon can more accurately reduce.Improvements in computed tomography (CT) and magnetic resonance imaging (MRI) scanning mean that complex fractures can be studied in great detail preoperatively, which assists the planning of surgery.

Figure 2 Reduction and healing of a fractured shaft of tibia showing the developing callus formation

Pain management

In arm fractures in children, ibuprofen has been found to be as effective as a combination of acetaminophen and codeine

Immobilization

The objectives of immobilising a fracture are:

To maintain the reduction

To provide the optimal healing environment for the fracture;

• To relieve pain.

Methods of Immobilization (fracture fixation)

Fixation can be either external (cast,splint,traction,external fixator, and lizarof) or internal such as (intramedullary nail, and plate and screws)

The biomechanics of fixation is based on either stress-sharing or stress-shielding devices. A stress-sharing device permits partial transmission of load across the fracture site. When a fracture is treated with a stress-sharing device, micromotion at the fracture site induces secondary bone healing with callus formation.Casts, rods, and intramedullary nails are examples of stress-sharing devices. A stress-shielding device shields the fracture site from stress by transferring stress to the device. The fractured ends of the bone are held under compression, and there is no motion at the fracture site. Stressshielding devices result in primary bone healing without callus formation. Compression plating is an example of this type of treatment. Bone healing in fractures that heal with callus formation (secondary bone healing) is relatively fast. Fractures that heal without callus formation (primary bone healing) heal more slowly. Thus, the amount of time that protected weight bearing is necessary varies not only with the location of the fracture but with the rate of bone healing.

TABLE 1 *Principles* of *Fixation Devices*

	Cast	Rod	Plate	Pin, Screw, or Wire	External Fixator
Type of fixation	Short or long	Reamed or unreamed	Compression		Exoskeleton
Biomechanics	Stress sharing	Stress sharing	Stress shielding	Stress sharing	Stress sharing
Type of bone healing	Secondary (callus)	Secondary (callus)	Primary (no callus)	Secondary (callus)	Secondary (callus)
Rate of bone healing	Fast	Fast	Slow	Fast	Fast
Weight bearing	Early	Early	Late	Delayed	Early
Addendum	Most frequently used form of treatment	Reamed: most frequently used Unreamed: used in open fractures of the tibia	Requires secondary support	Frequently used with other fixation	Mainly used with associated soft tissue injuries

Methods of External fixation
1-CASTS (plaster of Paris)

A cast is a stress-sharing device. Stress sharing allows for callus formation and thus relatively rapid secondary bone healing. The joint above and the joint below the fracture are immobilized in the cast to prevent rotation and translation of the fracture fragments. Early weight bearing is allowed if the fracture pattern is stable, as in a transverse midshaft fracture of the tibia. Occasionally, weight bearing must be delayed until sufficient callus has developed to prevent displacement, as in an oblique midshaft fracture of the tibia (Figures 3A, and 3-2B).

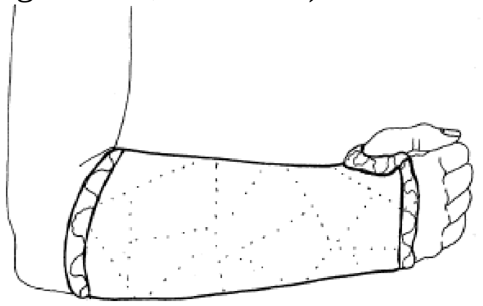


FIGURE 3-1 Forearm cast; a stress-sharing device.

FIGURE 3-B Cast treatment of a tibia fracture; a stresssharing device.

Types of cast

Below Knee Cast (Short Leg Cast)

This should support the metatarsal heads.

The ankle should be placed in neutral; apply with the knee in flexion.

Ensure freedom of the toes.

Build up the plantar surface for walking casts.

Fiberglass is preferred for durability.

Pad the fibula head and the plantar aspect of the foot.

Above Knee Cast (Long Leg Cast)

Apply below the knee first.

Maintain knee flexion at 5 to 20 degrees.

Mold the supracondylar femur for improved rotational stability.

Apply extra padding anterior to the patella.

Short and Long Arm Casts

The metacarpophalangeal (MCP) joints should be free.

Do not go past the proximal palmar crease.

The thumb should be free to the base of the metacarpal; opposition to the fifth digit should be unobstructed.

Even pressure should be applied to achieve the best mold.

Avoid molding with anything but the heels of the palm to avoid pressure points.

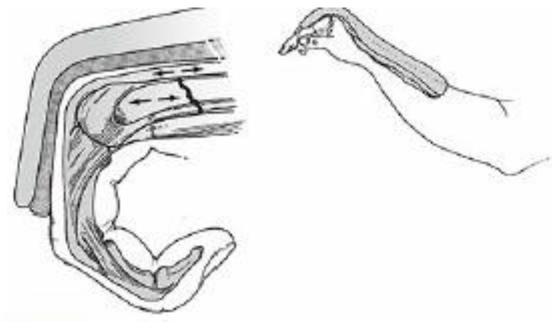
The advantages and disadvantages of plaster of Paris

Advantages	Disadvantages
• No surgery or its complications • No infection risk • Quick to apply • Rapid patient discharge • Cheap, relatively easy to apply with training • New lightweight casts are an alternative • Radio translucent (bones can be X-rayed through the cast) • May absorb fluids or bleeding. The extent of bleeding can be traced on the cast itself and monitored daily • Can be moulded for several minutes before hardening	• It may not be possible to reduce the fracture correctly or maintain reduction • May require surgery at a later date • Plaster needs removal/ or windowing (removal of a piece of the cast) to inspect the skin • May need removal in case of increased swelling or reapplication once swelling has subsided • Bad odour if it gets wet • Heavy • May crack • May rub the skin and cause sores

POSITIONS OF FUNCTION

■ **Ankle:** neutral dorsiflexion (no equinus)

■ **Hand**: MCP flexed (70 to 90 degrees), interphalangeal joints in extension (also called the intrinsic plus position) (Fig. 4)



POSITIONS OF FUNCTION for MCP FIGURE 4-

Functional bracing (cast bracing)

It has been found unnecessary to fix some fractures as rigidly as was thought necessary in the past. An example of this is cast (or functional) bracing. Functional braces have hinges to allow movement (Figure 5).

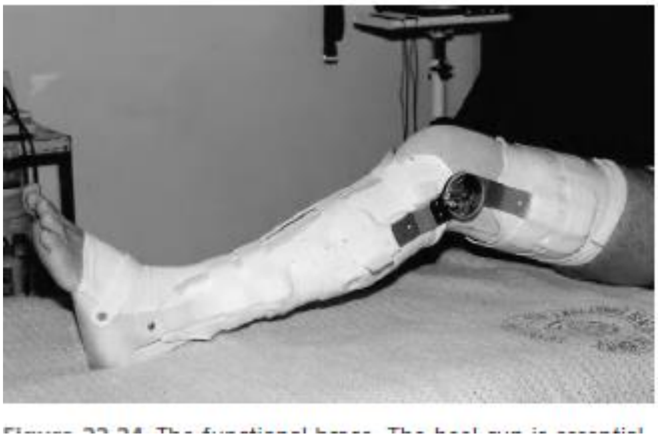


Figure 5 The functional brace. The heel cup is essential for correct off-loading of weight from the fracture.

2- SPLINTING TECHNIQUES

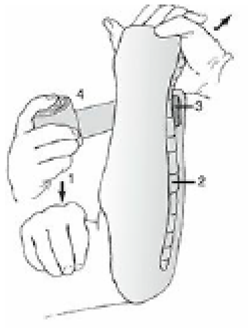
Splints may be prefabricated or custom made.

"Bulky" Jones (refers to padding)

It is Lower extremity splint, commonly applied for foot and ankle fractures and fractures about the knee, which uses fluffy cotton or abundant cast padding to help with postinjury swelling. The splint is applied using a posterior slab and a U-shaped slab applied from medial to lateral around the malleoli for ankle/tibia or a knee immobilizer for knee injuries. The extremity should be padded well proximal and distal to the injury.

■ Sugar-tong splint

It is Upper extremity splint for distal forearm fractures that uses a U-shaped slab applied to the volar and dorsal aspects of the forearm, encircling the elbow (Fig. 6).



(Fig. 6).Sugar-tong splint

■ Coaptation splint

It is Upper extremity splint for humerus fractures that uses a U-shaped slab applied to the medial and lateral aspects of the arm, encircling the elbow and overlapping the shoulder.

Ulnar gutter splint

Volar/dorsal hand splint

Thumb spica splint

Posterior slab (ankle) with or without a U-shaped splint

Posterior slab (thigh)

Knee immobilizer

Cervical collar

Pelvic sheet/binder

3-External fixator

Figure 7 shows fixation of a fractured tibia using an external fixator. Pins or wires are driven into the fragments and held by a piece of apparatus on the outside of the body. Figure 8 shows an external fixator for a comminuted intra-articular fracture of the distal radius. Figure 9 shows an external fixator for an unstable pelvic fracture.

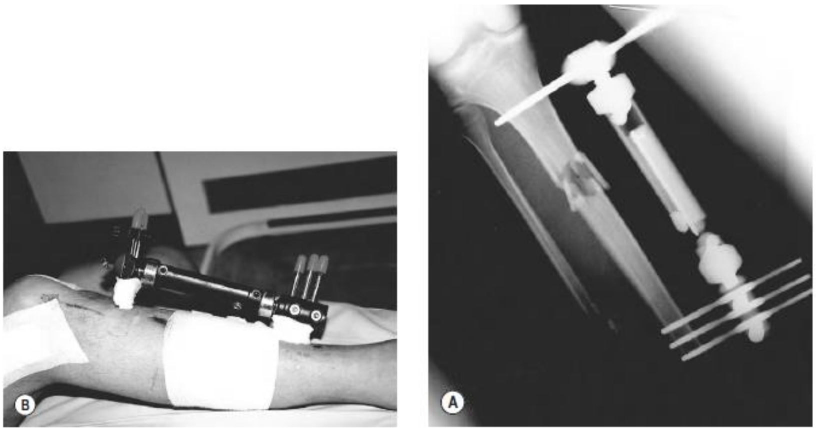


Figure 7 Fixation of a fractured tibia using an external fixator. Pins or wires are driven into the fragments and heldby a piece of apparatus on the outside of the body, as shown in the external view

Figure 8 Fixation of a comminuted intra-articular fracture of the distal radius

Figure 9 External fixator for an unstable pelvic fracture.

Advantages and disadvantages of external fixation

Advantages	Disadvantages
• Minimal disruption to the fracture site • Enables inspection of the wound and fracture • Can be adjusted with minimal trauma • Can be used for limb lengthening procedures • Can be used to pin multiple fragments (e.g. comminuted fractures) • Allows preservation of tissues in open or compound fractures, de-gloving injuries or burns	• Infection risk at pin sites • Needs meticulous wound care • Cosmetically ugly • Functional impairment (e.g. adjacent joints may be restricted or soft tissues pierced by fixator) • Anaesthetic risk and its associated complications • Patient will need several days in hospital • Stresses taken by implant, so decreased stimulus for callus formation • Heavy

Statement	Consequence for the physiotherapist
No two orthopaedic patients are alike	Do not ask for a 'treatment recipe'. Your approach should be flexible and dynamic and will change as a result of many factors
No two assessments are alike	Learn the basic assessment framework but tailor your assessment slightly to each individual
No two treatment courses are alike. Patients do not always do what the textbook says!	Keep an open mind, recognise when a treatment is not working and change or modify it
No single assessment can predict the outcome of the problem	Experienced physiotherapists are able to 'assess as they treat'. This means that the patient is continually receiving the most appropriate attention and the situation is dynamic. Treatment goals may need modification and should not be totally inflexible

4-The Ilizarov method

The Ilizarov method of fracture fixation originated in Russia in the 1940s. It incorporates an axial system of wires or pins fitted through the bone and connected to a circular ring. It has proved successful in cases of non-union.This method also incorporates

the principle of 'distraction osteogenesis', and can be used in the restoration of large skeletal defects, limb lengthening and the correction of skeletal deformities (Figure 10).

Figure 10 Ilizarov fixation for fractured humerus and scapula.

5-Traction

Traction is the application of a pulling force to a part of the body; it may be either a direct or an indirect pull. Traction is less common on the orthopaedic ward nowadays, although it still has its place. Uses include:

• restoring bone or limb length if it has been reduced by fracture or disease;

maintaining correct limb length and overcoming

muscle spasm, which may be the cause of limb shortening after a fracture;

to correct deformity in a joint;

to reduce a dislocated joint;

to immobilise a joint;

to relieve pain pre-operatively;

to promote rest and healing postoperatively

Types of traction

Skin Traction

Limited force can be applied, generally not to exceed 10 lb.

This can cause soft tissue problems, especially in elderly patients or those with or rheumatoid-type skin.

It is not as powerful when used during operative procedures for both length and rotational control.

Buck’s traction uses a soft dressing around the calf and foot attached to a weight off the foot of the bed.

This is an option to provide temporary comfort in hip fractures and certain children’s fractures.

A maximum of 7 to 10 lb of traction should be used.

Watch closely for skin problems, especially in elderly or rheumatoid patients.

Figure 11 shows an example of skin traction. The traction force is applied through the skin instead of through the bone.

Figure 11 Skin traction – this woman sustained a fractured shaft of femur and, owing to her general health, surgery was not indicated. She was managed conservatively.

Skeletal Traction (Fig. 12)

This is more powerful, with greater fragment control, than skin traction.

It permits pull up to 15% to 20% of body weight for the lower extremity.

It requires local anesthesia for pin insertion if the patient is awake.

Local anesthetic should be infiltrated down to the sensitive periosteum.

It is the preferred method of temporizing long bone, pelvic, and acetabular fractures until operative treatment can be performed.

Choice of thin Kirschner wire (K-wire) versus Steinmann pin

K-wire is more difficult to insert with a hand drill and requires a tension traction bow (Kirschner).

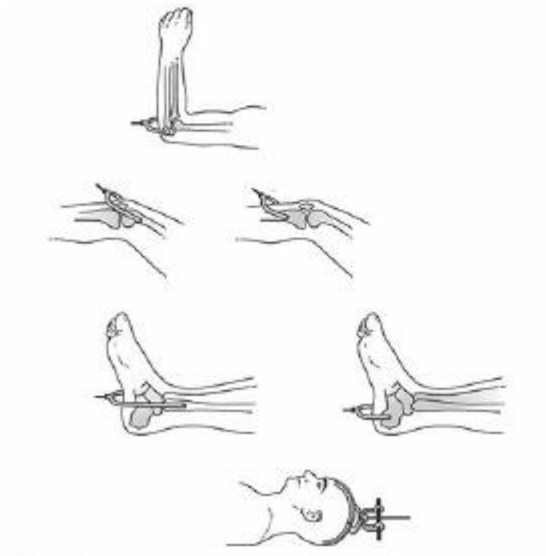
The Steinmann pin may be either smooth or threaded.

A smooth pin is stronger but can slide through bone.

A threaded pin is weaker and bends more easily with increasing weights, but it will not slide and will advance more easily during insertion.

In general, the largest pin available (5 to 6 mm) is chosen, especially if a threaded pin is selected. These pins are usually tolerated well and are not as painful as they appear.

ese pins are usually tolerated well



they appear.

(Fig. 12) Skeletal Traction

Methods of internal fixation

1-Intramedullary Rods And Nails

These are stress-sharing devices that allow for callus formation and fairly rapid secondary bone healing. An intramedullary rod or nail provides good fixation and allows the joints above and below the fracture to remain free for early mobilization. These devices are most frequently used in femoral shaft and tibial shaft

fractures and occasionally in humeral shaft fractures. Reamed nails have a large transverse diameter, making them very strong. However, reaming may disrupt the blood supply in the intramedullary canal, slowing endosteal bone healing. Reamed nails are frequently used in tibial and femoral shaft fractures. They may be statically locked by passing two screws transversely through both cortices of the bone and through the nail or rod, both proximally and distally. This rigid fixation prevents shortening and rotation at the fracture site, especially if the fracture is comminuted.

Even statically locked nails allow for some early weight bearing. Once the fracture develops callus, the proximal or distal screw fixations may be removed to dynamize or create compression at the fracture site to further

enhance bone healing. Weight bearing is allowed to create compression at the fracture site. Reamed nails are most frequently used in tibial and femoral shaft fractures (Figures 13, 14, and 15.

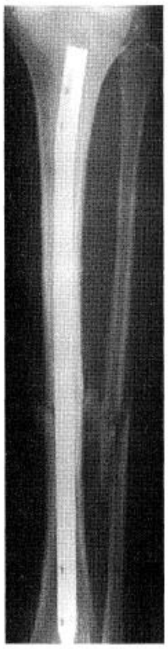


FIGURE 13 *(above, left)* Unlocked tibia nail; a stress-sharing device.
FIGURE 14 *(above, middle)* Statically locked nail; a stress-sharing device.
FIGURE 15*(above, right)* Dynamically locked reamed tibia nail; a stress-sharing device.

Unreamed nails are smaller in diameter and therefore tend to have less strength, although they may maintain a better endosteal blood supply. Unreamed nails are most often used with open fractures. They may be used in a statically locked, dynamically locked, or unlocked position. They are used less frequently than reamed nails.

2-Compression Plates

Compression plates are narrow, rectangular metal plates with curved surfaces that fit on the surface of the bone and are attached by screws in such a way as to create compression at the fracture site. They allow for anatomic reduction and fixation of the fracture (Figures 16, 17, and 18). These plates are stressshielding devices because the area of the fracture under the plate is under diminished load. In time, the cortices of the bone under the plate may be thinned because they have been shielded from stress and have a reduced blood supply. Compression plates are used most frequently in the upper extremity, particularly the radius and ulna. Primary bone healing occurs because of the rigidity of the fixation, compression at the fracture site, and anatomic reduction. Because primary bone healing is a slow process, compression plate fixation requires a long period of nonweight bearing (3 months) to prevent hardware failure. Before fracture healing, all weight is borne by the hardware, which may not withstand early cyclical loading. Secondary support of the fracture site is usually needed, such as a cast or splint (Figure 19).

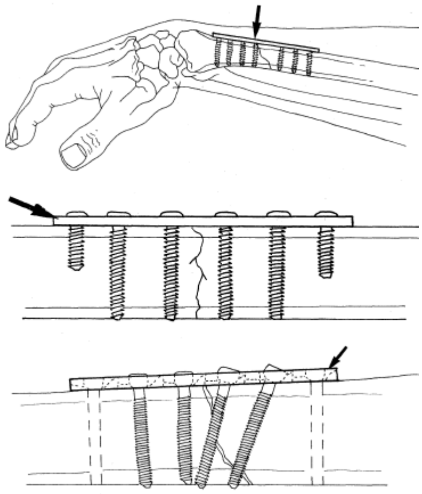


FIGURE 16 *(top)* Compression plating for diaphyseal forearm fractures; a stress-shielding device.
FIGURE 17 *(middle)* Tension band plating.
FIGURE 18 *(bottom)* Compression plate. Frequently used to treat forearm fractures, this is a stress-shielding device.

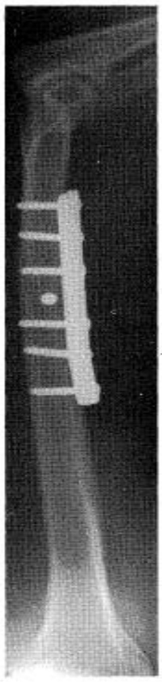


FIGURE 19 Compression plating of a humeral fracture. This is a stress-shielding device. If fixation is not rigid, it becomes a stresssharing device.

3-BUTTRESS PLATES

These thin metal plates are used most frequently on the proximal tibia after tibial plateau fractures. They are used in conjunction with lag and wood screws to create anatomic reduction of the fracture. Buttress plates are stress-sharing devices. The patient is initially kept from weight bearing (Figure 20)

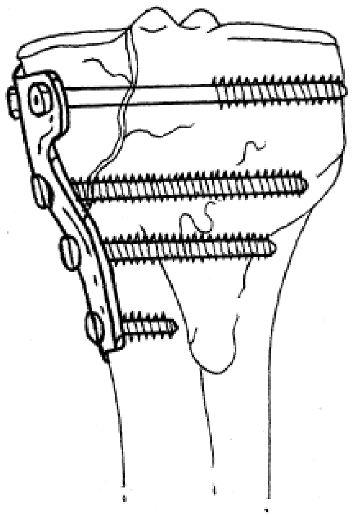


FIGURE 20 Buttress plate with screws creating a lag effect. And plain wood screws holding the plate to the bone

4-PINS, WIRES, AND SCREWS

Kirschner wires (K-wires), pins, and screws are thin metal devices that provide partial immobilization at the fracture site; they may be threaded (screws) or nonthreaded (K-wires and pins). They are all stresssharing devices that allow micromotion at the fracture site and therefore secondary bone healing. These

devices may be used independently or with another type of fixation, such as a cast, to produce further immobilization. Weight bearing is usually delayed. Pins, K-wires, and screws are frequently removed after bone healing has occurred. These devices are often used in ankle, patellar, metacarpal, and olecranon fractures (Figure 21)

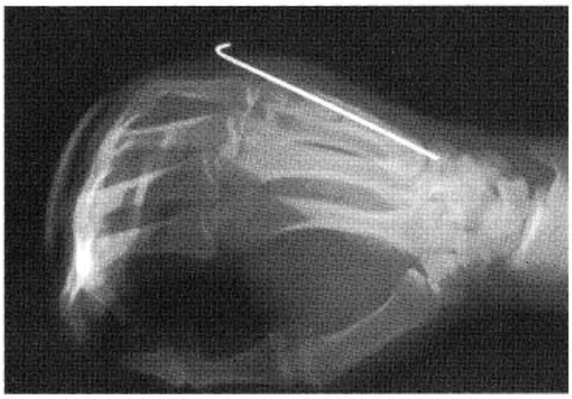


FIGURE 21 Metacarpal fracture treated with K-wire fixation; a stress-sharing device.

5-Compression Screws

Compression screws draw fragments of bone together. The smooth barrel of the screw crosses the fracture site, and the threaded portion extends into the distal or lateral part of the fracture. When the screw is tightened, the fragments are drawn together in what isknown as the lag effect. This is a stress-sharing device, and therefore weight bearing is usually delayed (Figure 22).

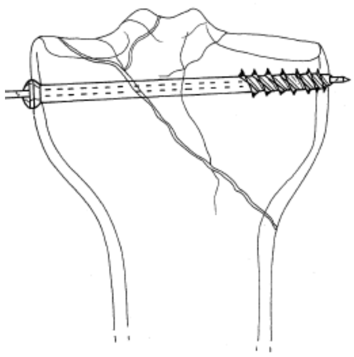


FIGURE 22 Cannulated screw with lag effect used to treat tibial plateau fractures

6-Sliding Hip Screw And Plate

This is a special device used for fixation of fractures at the proximal end of the femur. A sliding hip screw is a stress-sharing device. It is most frequently used with intertrochanteric fractures of the femur. Because of the comminution at the fracture site, it is difficult to have the fracture rigidly fixed (Figure 23)

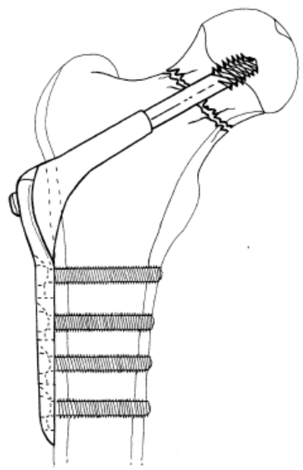


FIGURE 23 Sliding hip screw and plate used to treat a femoral neck fracture. This device is used most frequently for intertrochanteric fractures. It is usually a stress-sharing device, especially in comminuted fractures

7- 95-Degree Condylar Compression Plate

Fixation with the 95-degree condylar compression plate is frequently used for supracondylar fractures of the distal femur. This is a stress-sharing device because it is difficult to fix these fractures rigidly, but when a fracture is rigidly fixed, the 95-degree compression plate is a stress-shielding device (Figure 24

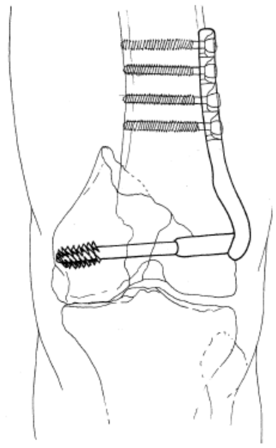


FIGURE 24 The 95-degree dynamic compression condylar plate used to treat supracondylar fractures of the femur. When rigidly fixed, this is a stress-shielding device, but it is usually a stress-sharing device

Therapeutic Exercise and Range of Motion

The ultimate purpose of an exercise program is to restore function, performance, muscle strength, and endurance to pretrauma levels. Unused muscles atrophy and lose strength at rates from 5% per day to 8% per week. With immobilization, atrophy is found in both slow-twitch (type one) and fast-twitch (type two) muscle fibers. Fast-twitch fiber atrophy is first seen as a loss in strength, whereas atrophy of slow-twitch fibers is noted as a loss of endurance.

Muscle strength is basically the ability of the muscle to contract against resistance. The basic principle of strength training is to use resistance and repetitive contraction to promote recruitment of all muscle motor units; this is done each day at an intensity that does not overload the muscle. An example of this is the leg press exercise, where the quadriceps muscles are strengthened by extending the knee against progressively heavier weight. This is done until a sense of fatigue is experienced, but not to the point of pain or exhaustion.

Endurance is the ability to do the same movement repeatedly. This is achieved by repetitive exercise until the muscle fatigues (overload). Examples of endurance exercise include walking for increasing distances, repetitively contracting the gastrocnemius after a tibial fracture, or repetitively contracting the quadriceps after a femoral fracture. The best exercise to improve the performance of a task is the repeated performance of the task itself, such as walking or washing the hair. Exercise performed by the patient accomplishes the goals of maintaining range of motion and increasing strength and endurance. These are important to improve the patient's ability to perform a given function or task. The following types of exercises are most frequently prescribed for a comprehensive exercise program.

Range Of Motion

The movement of a joint through partial or full excursion, range of motion is performed to maintain or increase the excursion of a joint. It is the most basic type of exercise prescribed in all phases of fracture rehabilitation. Range of motion may be full (anatomIc) or functional (the movement required to perform a specific task).

Full Range of Motion

Full range of motion is the available range of motion of a given joint as defined by its anatomy. The restriction of movement by the bony configuration of the joint, as well as ligamentous checks, determines the possible joint excursion, or range of motion. For example, the knee has a range of motion of 0 to 120 degrees (full extension, 0 degrees, to full flexion, 120 degrees).

Functional Range of Motion.

Functional range of motion is the movement required from a specific joint for the performance of activities of daily living or for any patient-specific task (e.g., pitching a baseball). To sit comfortably, for example, 90 degrees of flexion at the knee is desirable. A range of motion at the knee from full extension (0 degrees) to 90 degrees of flexion is not full, but it is functional for sitting.

Active Range of Motion

The patient is instructed to move the joint throug? full or partial available motion on his or her own volItion. The purpose of active range of motion exercise is to prevent loss of available movement at the joint. These exercises are indicated in the early phase of bone healing when there is no or little stability at the fracture site. Direct patient sensory feedback helps to prevent motion that might increase pain or affect the stability of the fracture site.

Active Assistive Range of Motion

In this exercise, the patient is directed to use his or her own muscle contraction to move a joint, while the treating professional provides additional or assistive force. This is most commonly used in instances of weakness or inhibition of motion due to pain or fear, or to increase the available range of motion. Some stability at the fracture site, such as that provided by bone healing or fracture fixation, is required for this exercise.

Passive Range of Motion

These exercises consist of joint movement without patient muscle contractions. All motion is provided by the physician or therapist. The purpose of this exercise is to maintain or increase the available motion at a joint, depending on the force applied. These exercises are indicated when voluntary muscle contraction is impossible, undesirable, or not strong enough to overcome joint capsule contracture. Because of the decreased direct sensory feedback to the patient, passive range-of-motion exercises should not be prescribed when excessive joint movement might affect the stability of a healing fracture.

MUSCLE STRENGTH GRADING

Although uncomplicated fractures do not present neurologic problems, the muscles surrounding the site of fracture are weaker, usually secondary to direct trauma, immobilization, or reflex inhibition. Muscle testing is a useful guide for evaluating the improvement in muscle strength during the recovery period.

TABLE 2 *Muscle Grading Chart*

Muscle Gradations	Description
5—Normal	Complete range of motion against gravity with full resistance
4—Good	Complete range of motion against gravity with some resistance
3—Fair	Complete range of motion against gravity
2—Poor	Complete range of motion with gravity eliminated
1—Trace	Evidence of slight contractility; no joint motion
0—Zero	No evidence of contractility

STRENGTHENING EXERCISES

Strengthening exercises increase the amount of force that a muscle can generate. These exercises improve the coordination of motor units innervating that muscle as well as the balance between muscle groups acting at a given joint. Strengthening exercise is geared to increase the potential tension that can be produced by contractile and static elements of the muscle-tendon unit. Strengthening exercises are of various types.

Strengthening Exercises after Fracture

Effects of Exercise	Isometric	Isotonic	Isokinetic
Muscle length	No change	Shortens and lengthens	Shortens and lengthens
Joint motion	No	Yes	Yes—constant rate of motion
Muscle fiber tension	Increases	Increases initially, then there is constant tension throughout the range of motion	Increases
Strength gain	In one joint position	Throughout the range of motion; maximal gain at the ends of joint range	Equal gain throughout the range of motion
Effect on range of motion	No change	Maintains or increases	Maintains or increases
Timing of exercise	Early stage	Intermediate stage	Late stage
Example of strengthening exercise	Contracting the biceps while in a long arm cast	Biceps curl	Biceps curl performed on a machine that varies resistance to allow for a constant rate of motion

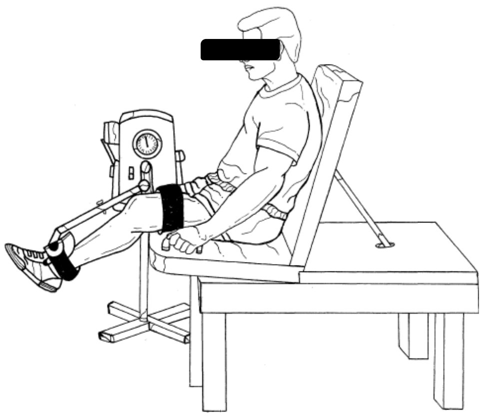


FIGURE 25 Isokinetic exercise. During this exercise, the joint moves at a constant rate, but the resistance applied is variable. The muscle can be optimally strengthened through the joint's entire range of motion. These exercises are prescribed ill the late stage of rehabilitation when there is good stability at the fracture site

High-Performance Strengthening Exercise Closed-Chain Exercise

This type of exercise requires fixation of the proximal and distal portions of the body that are being moved during exercise. Closed-chain exercises are good for strengthening multiple muscle groups simultaneously and have the added value of enhancing function, because most "real-life" movements occur in a closed kinetic chain. Examples of closed-chain exercise include wall slide exercises and squats, both of which strengthen all the major extensor muscle groups of the lower extremities (the closed kinetic chain includes the ankle, hip, and knee joints).

Open-Chain Exercise

In this exercise, there is no fixation of the distal limb. This type of strengthening exercise is more commonly prescribed after fracture. Examples include leg or biceps curls.

Plyometric Exercise

This exercise is performed by maximal muscle contraction after a quick stretch, such as jumping and hopping exercises. Because of the torque generated at a lower extremity fracture site, these exercises should be prescribed only in the late phase of rehabilitation to enhance the patient's strength and performance beyond that required for routine activities of daily living. Open-chain, closed-chain, and plyometric exercises may be prescribed for specific tasks or levels of performance as part of the rehabilitation program after fracture. For example, closed-chain or plyometric exercises may be prescribed to achieve the strength required for athletic performance (jumping; strengthening the gluteal and quadriceps muscles after a femur fracture), or open-chain biceps curls prescribed for isolated strengthening of the biceps after humeral fracture.

Functional Or Task-Specific Exercise

These exercises increase performance while increasing strength. In addition to muscle fiber hypertrophy, they improve neuromuscular coordination, agility, and strength. Examples of this type of exercise include stair climbing after femoral fracture or ball squeezing and turning door knobs after the removal of a cast for a Colles' fracture.

Conditioning Exercise

Conditioning exercises increase endurance. They are used to increase overall cardiopulmonary function rather than to treat deficits after a specific fracture. Conditioning exercises enhance peripheral oxygen utilization and muscular efficiency and result in aerobic muscle metabolism. They are performed at an adequate target heart rate for more than 20 minutes. Common conditioning exercises include riding a stationary bicycle or using a treadmill.

TYPES OF MUSCLE CONTRACTION DURING EXERCISE

Muscles contract in various ways to allow smooth function of the joints. There is a "traditional" or shortening contraction that flexes the joint, an elongation contraction that allows the joint to extend in a controlled manner, and a contraction that produces no motion. Rehabilitation considerations for specifying the type of contraction by which a muscle is exercised are based on the stability of the fracture site, the effect of joint motion on the fracture site, the rapidity of muscle fatigue, and any selective muscle strengthening necessary to perform a specific task. They are concentric, eccentric, and isometric.

	Concentric	Eccentric	Isometric
Fiber length	Shortens	Lengthens	No change
Joint motion	Accelerates	Decelerates	None
Force of contraction	Less	Greater	Great
Quadriceps muscle contraction	Knee extension	Progressive knee flexion—squatting	Stabilizes the knee in fixed flexion—squatting position

Modalities Used in the Treatment of Fractures

Physical therapeutic treatment modalities (i.e., heat and cold, hydrotherapy, fluidotherapy, and electrical stimulation) are frequently used after a fracture to reduce discomfort and enhance the effects of exercise. Modalities all have a predictable biologic effect when externally applied. Just as with pharmacologic treatments, the rehabilitation prescription for these modalities must take into account indications, contraindications, and possible adverse reactions, as well as dosage and frequency of application. It is necessary to be familiar with the specific physiologic effects of the various modalities to use them properly.

Heat Modalities

Modality	Tissues Heated	Indications	Contraindications	Frequency of Use
Superficial heat				
Hot packs,	Skin and subcutaneous	Pain and muscle tension	Burn or anesthetic area Peripheral vascular disease	Common
Paraffin bath;	Skin and subcutaneous	Pain and muscle tension Reduced range of motion	Burn or anesthetic area Peripheral vascular disease	Common
Fluidotherapy*	Skin and subcutaneous	Reduced range of motion Pain and muscle tension	Burn or anesthetic area Peripheral vascular disease Ischemic area Bleeding	Common
Deep heat				
Ultrasound	Bone/muscle	Contracture of muscle or joint capsule	Local fracture Metal implant	Occasional
Short-wave diathermy	Subcutaneous	Postoperative adhesion, superficial contracture	Metal implant Pacemaker Drug delivery system	Rare
Microwave diathermy	Muscle	Muscle contracture	Metal implant Pacemaker Drug delivery system	Rare

*Prolonged immersion may provide deep heat to small, superficial joints such as the digits.

Therapeutic Cold

Cold, applied either by an ice pack or other type of cold pack, or by the use of a vapocoolant spray that cools by evaporation, is most often used very early in fracture rehabilitation for analgesia and control of edema immediately after injury. Cold produces its numbing effect by decreasing the firing rate in peripheral receptors, including pain receptors. In the later phases of rehabilitation, therapeutic cold is useful for reducing pain and muscle spasm, but is used less often than heat and hydrotherapy modalities. The use of cold versus heat for pain reduction is patient specific. The most effective modality for the individual patient is the one that should be used.

Hydrotherapy

Hydrotherapy may include whirlpool or therapeutic pool treatment, depending on the desired therapeutic effect. The benefits of therapeutic heat and exercise are often synergistic when applied in conjunction with hydrotherapy. The general uses of hydrotherapy are to:

1) Improve range of motion, especially after cast removal Stimulate wound healing (by mechanical debridement and cleansing the skin of excess corneum collected under the cast).
2) Improve circulation (depending on water temperature).
3) Increase weight acceptance by a lower extremity. The degree of weight bearing, a product of buoyancy and gravity, can be varied by adjusting the height 30 / Treatment and Rehabilitation of Fractures of the water. Treatment in a walk-tank or therapeutic pool is a good way to advance weight bearing.

Electrical Modalities

Electrical stimulation may be provided as part of a strengthening program after a fracture has healed, particularly when patient anxiety has led to the inhibition of contraction. In select instances, high-volt galvanic (direct current) stimulation may be useful to reduce muscle spasm, particularly when this is necessary to increase range of motion after cast removal (e.g., to stimulate the quadriceps after a distal femur fracture).

Spray And Stretch

Spray and stretch therapy consists of slow, unidirectional application of a vapocoolant (fluorimethane) followed by manual stretching. If there is persistent muscle spasm after fracture healing, especially of the cervical/scapular or lower back muscles, this can be useful to help stretch and relax the muscle, leading to reduced pain and improved range of motion.

Gait

The purpose of the lower extremities is ambulation. After fracture of a lower extremity, this function is compromised. When the clinician evaluates the quality of ambulation, gait becomes a focus of concern. Gait is the manner in which a person ambulates. A careful assessment of gait identifies problems that result in inefficient or limited ambulation and allows for their treatment.

The goal of rehabilitation of lower extremity fractures is the restoration of normal gait to the preinjury level of function whenever possible. Therefore, it is essential for the practitioner to understand all aspects of normal gait.

The Gait Cycle

The gait cycle describes the activity that occurs during ambulation. It is divided into two phases, the stance and the swing phase.

Components of the Gait CYCLE

Standard Classification	Alternate Classification[a]
Heel-strike	Initial contact
Foot-flat	Loading response
Mid-stance	Mid-stance
Heel-off	Terminal stance
Toe-off	Pre-swing
Acceleration	Initial swing
Mid-swing	Mid-swing
Deceleration	Terminal swing

The Gait Cycle In Fracture Rehabilitation

The gait cycle is a blueprint for muscle activity during human walking. Clinically, we identify muscles that may affect the fracture, usually the muscles that cross the fracture site. Because the principal goal of rehabilitation after a fracture of the lower extremity is to restore normal ambulation, it is important to evaluate the patient's gait to identify the deficits that will require attention. Understanding the gait cycle facilitates the identification of gait abnormalities and treatment goals in the 1ater stage of rehabilitation.

Key Lower Extremity Muscle Activity during the Gait Cycle

Phase	Muscle Contraction
Stance phase	
Heel strike	Hip: gluteus maximus Knee: quadriceps and hamstrings Ankle: tibialis anterior
Foot-flat	Hip: none Knee: quadriceps Ankle: tibialis anterior
Mid-stance	Hip: gluteus medius Knee: quadriceps Ankle: gastrocnemius-soleus
Heel-off	Hip: none Knee: quadriceps Ankle: gastrocnemius-soleus
Toe-off	Hip: none Knee: hamstrings Ankle: gastrocnemius-soleus
Swing phase	
Acceleration	Hip: iliopsoas Knee: quadriceps Ankle: tibialis anterior
Mid-swing	Hip: none Knee: quadriceps Ankle: tibialis anterior
Deceleration	Hip: gluteus maximus Knee: hamstrings Ankle: tibialis anterior

Concentric and Eccentric Activity during Normal Gait

Phase	Eccentric Activity	Concentric Activity
Heel-strike to foot-flat	Tibialis anterior Quadriceps Gluteus maximus Hamstrings Extensor hallucis Extensor digitorum	
Foot-flat to mid-stance	Quadriceps	
Mid-stance to heel-off		Triceps surae
Heel-off to toe-off	Quadriceps Gluteus medius (contralateral)	Triceps surae Tibialis anterior Peroneus longus Flexor digitorum Flexor hallucis
Toe-off to acceleration	Gluteus medius (contralateral)	Triceps surae Tibialis anterior Hamstrings
Acceleration to mid-swing	Gluteus medius (contralateral)	Quadriceps Iliopsoas Tibialis anterior
Mid-swing through deceleration	Hamstrings Gluteus medius (contralateral)	Tibialis anterior

Parameters of Gait

Parameter	Normal Value
Step angle	6–7 degrees external rotation
Step width	3–4 in.
Step length	15–20 in.
Stride length	30–40 in.
Cadence	120 steps/min
Speed	2.5–3 miles/hr

The Determinants of Gait

The determinants of gait are the movements that improve efficiency, minimize the energy expended in walking, and provide a smooth gait by minimizing the excursion of the person's center of gravity in the sagittal and coronal planes. The determinants of gait include pelvic tilt, shift, and rotation; hip-knee-ankle movement; knee flexion in stance; and ankle movement.

These movements can all be thought of as increasing or decreasing the functional length of a lower extremity, thereby reducing the amplitude of lateral and vertical (up-and-down motion) while walking. These determinants fine-tune gait and in general are not perceived as major factors in gait retraining because the patient usually compensates for them. If there is severe leg length discrepancy and severe loss of range of motion, and the patient is unable to compensate, then these determinants must be addressed.

Pelvic Tilt

During gait, the limb is functionally lengthened or shortened by anterior or posterior pelvic tilt. In fractures of the lower lumbar spine, tilt is reduced because of pain and stiffness.

Pelvic Shift

Lateral movement of the pelvis over the leg in stance serves functionally to lengthen the extremity and shift the center of gravity closer to the long axis of the limb. This both decreases the vertical amplitude of movement and provides a mechanical advantage to the gluteus medius to prevent dropping the contralateral hemipelvis in swing. Hip fractures and hip surgery impair the normal mechanics of pelvic shift, particularly when the gluteus medius is compromised. Because of pain, the patient is unable to shift the pelvis laterally.

Pelvic Rotation

The pelvis rotates medially (anteriorly) as the swing phase ends and stance begins, lengthening the limb as it prepares to accept weight. The opposite rotation (lateral or posterior) occurs as the leg leaves the stance phase, with functional shortening by lateral rotation decreasing the height needed to clear the swing-phase limb. Fractures of the hip or lumbar spine impair or prevent normal pelvic rotation during gait.

Hip-Knee-Ankle Movement

Flexion at the hip and knee and dorsiflexion of the ankle serve functionally to shorten a limb, whereas extension or plantar flexion at the joints makes the leg functionally longer. The net effect of this is to decrease vertical movement and concomitant energy cost while walking. Fractures of the femur or tibia disrupt the normal mechanics of hip-knee-ankle movement during walking. Hip, knee, or ankle fractures may prevent limb shortening during swing because of reduced motion and or pain.

Knee Flexion in Stance

This limits the maximum height a person achieves during gait, which reduces the up-down amplitude of movement, as illustrated by the ability to walk fully erect through a tunnel slightly too low to allow standing fully erect. Knee flexion in stance is abnormal with patellar or intraarticular knee fractures, leading to a reduced vertical amplitude or up-and-down movement.

Ankle Movement

Ankle and subtalar motion reduces energy cost by reducing the amplitude of movement and smoothing the translation of movement. Ankle and foot fractures prevent normal ankle motion during gait. This may persist once a fracture has healed because of muscle or other soft tissue contracture.

Arm swing, rotation of the femur and tibia, and trunk bending may also be considered determinants of gait because they serve to smooth transitions in direction of motion, further conserving both momentum and energy. An analysis of the determinants of gait becomes important in the late stage of rehabilitation after fracture, when more subtle deviations in the gait are identified so that normal ambulation may be restored as fully as possible. When actual shortening due to bone loss or functional shortening due to muscle shortening (e.g., inability fully to extend the hip or knee) occurs after a fracture, the determinants of gait are affected and must be corrected to restore normal ambulation.

Gait Deviations

Pathologic changes in gait after a lower extremity fracture occur as a consequence of shortening, weakness, pain, anxiety, or fear. A decrease in efficiency with reduced speed, increased energy cost, and loss of the normal cosmesis of gait result regardless of the specific abnormality.

If weakness or shortening persist, the initial pathologic gait changes as the body attempts to compensate for the problem. Although the gait remains abnormal in such an instance, the extra energy expended in ambulation is reduced. Once a fractured limb is fully weight bearing, the most common gait deviations are due to pain, weakness, or inefficiency of muscle contraction due to injury and pain, plantar flexion contracture, and lack of patient confidence.

Antalgic Gait

This painful gait IS an attempt to avoid bearing weight on the fractured lower extremity. In an antalgic gait, there is prolonged stance on the unaffected lower extremity, reduced step length on the unaffected side, and a prolonged period of double support; the goal is to minimize the time spent on the fractured limb. This may result from pain or anxiety and almost invariably follows any fracture of the lower extremity.

Short-Step Gait

Step length is reduced after any fracture of the lower extremity. This may be due to pain, anxiety, weakness or poor endurance.

Short-Leg Gait

If shortening has occurred after a lower extremity fracture, the patient attempts to limit the vertical excursion during gait. The opposite "long" leg may be "shortened" by abducting the leg, flexing the hip and knee more than usual (steppage gait), circumducting the leg, or raising the hemipelvis (hip-hiking).

Vaulting Gait

The patient may plantar flex the short limb, thus "lengthening" it by remaining on tiptoe. The patient jumps or a vault over the shortened limb, and this is called a vaulting gait.

Gluteus Maximus Lurch

In the case of gluteus maximus weakness, such as may follow a subtrochanteric fracture, the patient may experience difficulty preventing flexion of the trunk at heel strike (salutation gait). This is the uncompensated gluteus maximus lurch. If gluteal weakness persists, the patient may use trunk extension before heel strike to maintain balance (compensated gluteal lurch; Figure 26).

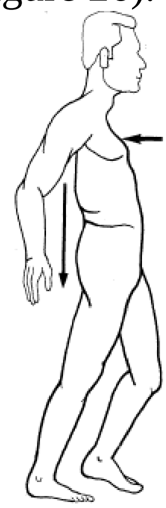


FIGURE 26 Gluteus maximus lurch. A patient with a weak gluteus Maximus muscle may experience difficulty in preventing flexion of the trunk at heel strike and may use trunk extension (gluteus maximus lurch) just before heel strike to maintain balance.

Gluteus Medius Lurch

After a trochanteric fracture, the gluteus medius is initially ineffective in preventing the drop of the contralateral hemipelvis during the swing phase. This is the gluteus medius lurch, or uncompensated Trendelenburg gait. If this lurch persists, a patient begins to shift weight over the fractured leg to shift the center of gravity over the supporting limb. This throwing of the trunk to the side of the impaired gluteus medius (lateral list) is the compensated Trendelenburg gait (Figure 27).

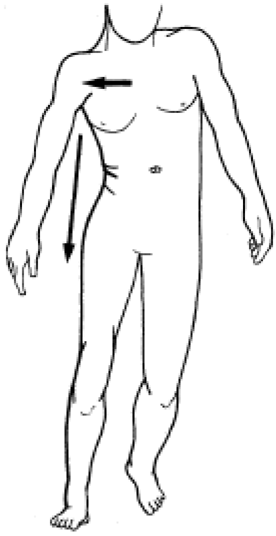


FIGURE 27 Gluteus medius lurch. A weak gluteus medius is ineffective in preventing the drop of the opposite hemipelvis during swing phase. To compensate, the patient shifts weight over the weak side to shift the center of gravity over the supporting limb. This throwing of the trunk to the side of the impaired gluteus medius is gluteus medius lurch.

Quadriceps Weakness

When there is weakness or inhibition of the quadriceps, such as after a patellar or distal femoral fracture, one of three basic compensations arise to prevent buckling at the knee. The limb may be externally rotated, to position the joint axis incongruent with the line of progression, thus preventing buckling. Alternatively, with a mild degree of weakness, hyperextension of the knee after heel strike prevents buckling; this is called *genu recurvatum.* Less frequently, the patient may manually assist the quadriceps by pushing backward on the thigh with the hands.

Steppage and Circumducted or Abducted Gait

This type of gait may result from peroneal nerve injury, from direct trauma, or from compartment syndrome after either soft tissue trauma or bleeding after a tibial fracture. To clear the foot during the swing phase, the patient may excessively flex the hip and knee to gain additional height (Figure 28).

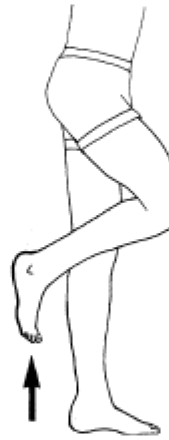


FIGURE 28 Steppage gait may occur from nerve or soft tissue trauma that leaves the patient unable to dorsiflex the foot in the swing phase. To clear the foot during swing phase, the patient may excessively flex the hip and knee to gain additional height. Alternatively, the patient may exaggerate abduction or circumduction of the fractured limb during the swing phase.

Quick Heel Rise

If shortening of the triceps surae has occurred, such as with an as calcis fracture, loss of dorsiflexion results in rapid heel rise. This manifests itself during the stance phase with early heel-off and a longer period of stance taking place on the forefoot.

Gait Considerations with Lower Extremity

Fracture

Weight-bearing status is defined as follows:

1. Non-weight bearing
2. Toe-touch weight bearing
3. Partial weight bearing; the degree of weight bearing is determined by the physician depending on the probable stability of the fracture at any given point

4. Weight bearing as tolerated
5. Full weight bearing.

Gait Patterns after Fracture

Common gait patterns after fracture can be classified by the type of step taken (step-to, step-through), or by the number of contact points used to take a step (two-, three-, or four-point gait). Because weight bearing on the affected extremity is restricted, the patient may use various gait patterns with crutches or other assistive devices.

Step-to Gait

In the step-to gait, the fractured limb is advanced, and then the intact limb brought to the same position. When weight-bearing status is restricted to partial, toe-touch, or as tolerated, crutches or a walker are necessary and help the patient step to the fractured limb by pushing down with the upper extremities, thus transferring weight from the fractured limb to the assistive device.

Example: Partial weight bearing or toe-touch weight bearing after a tibial shaft fracture, using a two-point gait. In this case, the partially weight-bearing limb and crutches are advanced, and then the intact limb is advanced to the same position.

Step-through Gait

In the step-through gait, the intact leg is advanced, and then the fractured leg is advanced past it. With restricted weight bearing, crutches are used instead of the injured limb, and the patient steps past the crutches with the weight-bearing lower extremity; the gait assumes a two-point or three-point pattern.

Example: Oblique midshaft tibial fracture that is non-weight bearing; the intact leg is advanced past the crutches and then the fractured leg and crutches are advanced past the intact limb (Figures 29, 30, and 31).

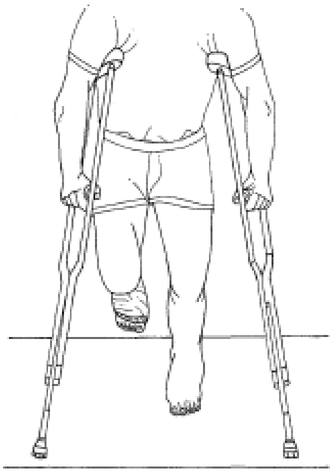
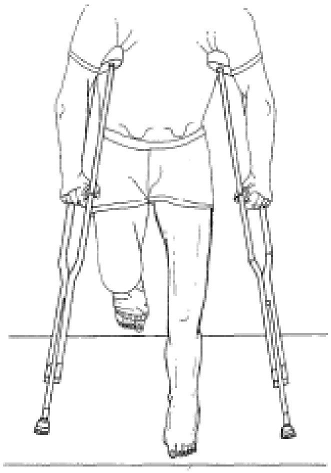
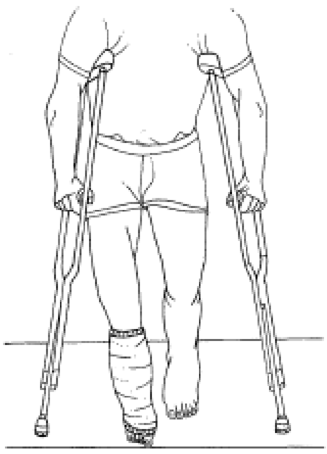




FIGURE 29 *(above, left)* Step-through gait starting position. With restricted weight bearing, crutches are used instead of the injured limb.

FIGURE 30 *(above, middle)* Step-through gait: the intact leg is advanced past the crutches.

FIGURE 31 *(above, right)* Step-through gait: the fractured leg and crutches are then advanced past the unaffected limb.

Gaits Used* on *level Surfaces

Two-Point Gait

In a two-point gait (sometimes called hop-to gait), the crutches and the fractured leg are one point and the uninvolved leg is the other point. The crutches and fractured limb are advanced as one unit, and the uninvolved weight-bearing limb is brought forward to the crutches as the second unit (Figure 32).

Example: A non-weight-bearing fracture of the femur used in a step-to gait pattern where the crutches are brought forward with the fractured limb and the intact limb steps up to the crutches.

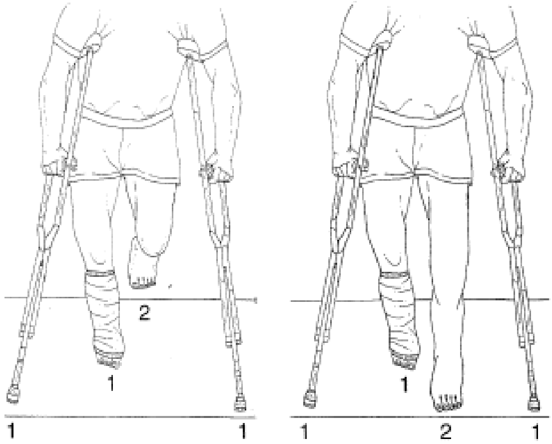


FIGURE 32 *(above. left) Two-point gaits* (hop-to gait). *(above, right)* The crutches and fractured leg are one point and the uninvolved leg is the other point. The crutches and fractured limb are advanced as one unit and the uninvolved weight-bearing limb is brought forward to the crutches as the second unit.

Three-Point Gait

In a three-point gait, the crutches serve as one point, the involved leg as the second point, and the uninvolved leg as the third point. Each crutch and the weight-bearing limb are advanced separately, with two of the three points maintaining contact with the floor at any given time (Figure 33).

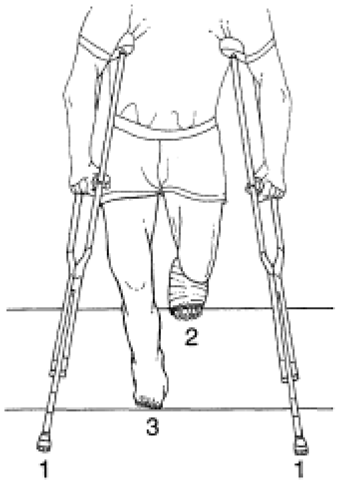


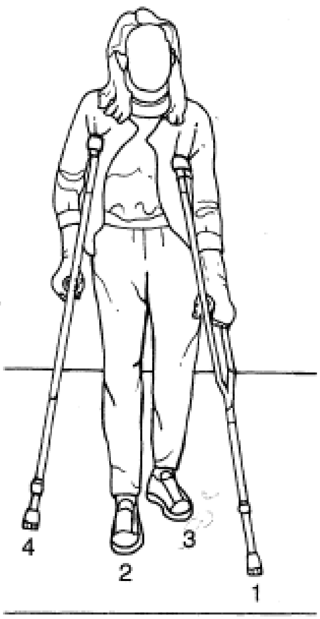
FIGURE 33 Three-point gait. The crutches serve as one point, the involved leg as the second point, and the uninvolved leg as the third point. Each crutch and weight-bearing limb is advanced separately, with two of the three points maintaining contact with the floor at any given time.

Example: A partially weight-bearing femoral neck fracture. In this instance, the crutches are advanced, the fractured limb is advanced next, and finally the intact limb is brought forward.

Four-Point Gait

In a four-point gait, point one is the crutch on the involved side, point two is the uninvolved leg, point three is the involved leg, and point four is the crutch on the uninvolved side (Figures 34 and 35). The crutches and limbs are advanced separately, with three of the four points on the ground and bearing weight any given time.

Example: A partially weight-bearing fracture with a secondary problem such as weakness, poor motor control, or anxiety. This type of gait is not efficient, but it does enhance stability or balance and may provide reassurance to an elderly patient experiencing significant fear or anxiety.



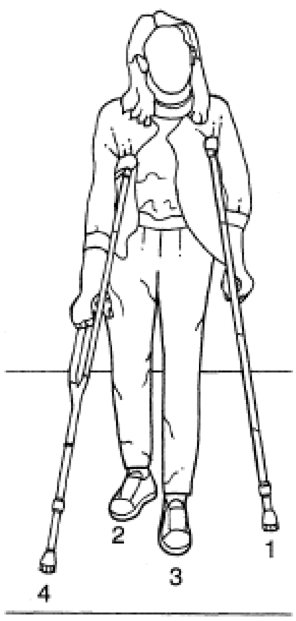


FIGURE 34 *(above. left)* Four-point gait. Point one is the crutch on the involved side, point two is the uninvolved leg, point three is the involved leg, and point four is the crutch on the uninvolved side.
FIGURE 35 *(above, right)* Four-point gait. The crutches and limbs are advanced separately, with three of the four points on the ground and bearing weight at any given time.

Gait Used **on** *Uneven Surfaces*

Patients with lower extremity fractures must also be taught how to negotiate uneven surfaces such as stairs and curbs. To reduce or eliminate weight bearing on the fractured extremity, the patient climbs stairs by ascending with the unaffected limb first and bringing the fractured limb up to meet it, either simultaneously with the crutches or by keeping the crutches on the step below until both feet are on the step above. The crutches are then brought up to the step (Figures 36, 37, and 38).

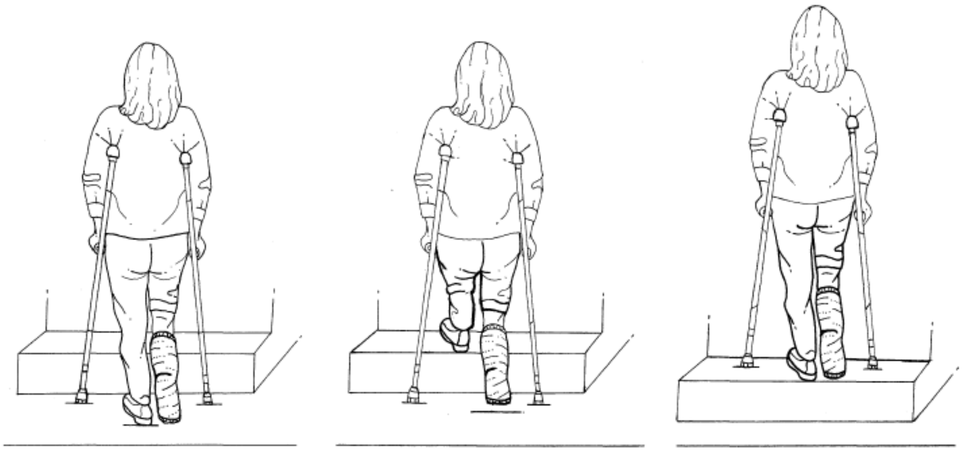


FIGURE 36 *(above. left)* Patients with lower extremity fractures must be taught how to negotiate uneven surfaces such as stairs and curbs.

FIGURE 37 *(above, middle)* To reduce or eliminate weight bearing on the fractured extremity, the patient climbs stairs by ascending with the unaffected limb first.

FIGURE 38 *(above, right)* After ascending with the unaffected limb first, the patient brings the fractured limb up to meet it, either simultaneously with the crutches or keeping the crutches on the step below until both feet are on the step above. The crutches are then brought up to the step.

The patient descends stairs with the fractured limb first, bringing the unaffected limb down to meet it. The crutches are placed on the step below, and then the fractured limb is brought down a step and the unaffected limb is brought last (Figures 39, 40, and 41).

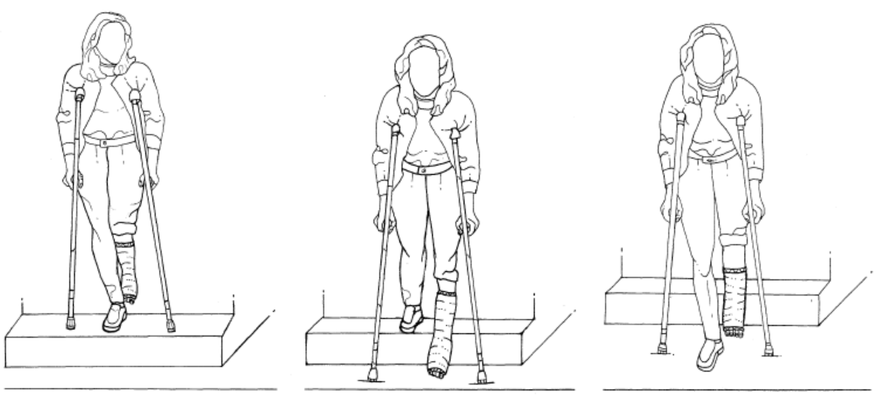


FIGURE 39 *(above, left)* The patient descends stairs with the fractured limb first, bringing the unaffected limb down to meet it.
FIGURE 40 *(above, middle)* The crutches are placed on the step below and then the fractured limb is brought down a step.
FIGURE 41 *(above, right)* The unaffected limb is brought down last.

An easy way to remember this approach is "the good go up to heaven and the bad go down to hell." If a banister is present and the patient is nonweight bearing, the patient uses one or two crutches together on the uninvolved side and holds the banister with the hand on the same side as the fracture. The uninvolved extremity is placed on the step above, and while the patient pulls up on the banister, the fractured limb and crutches are advanced and brought up a step (Figures 42, 43, and 44).

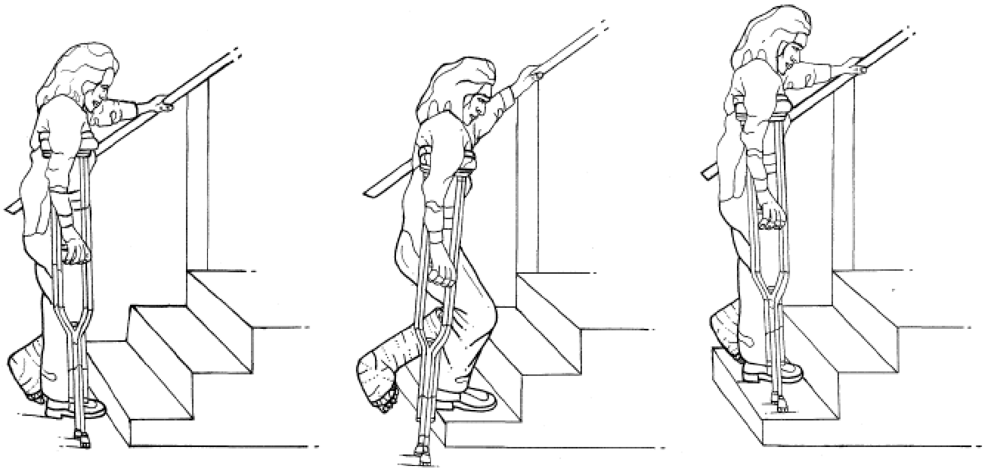
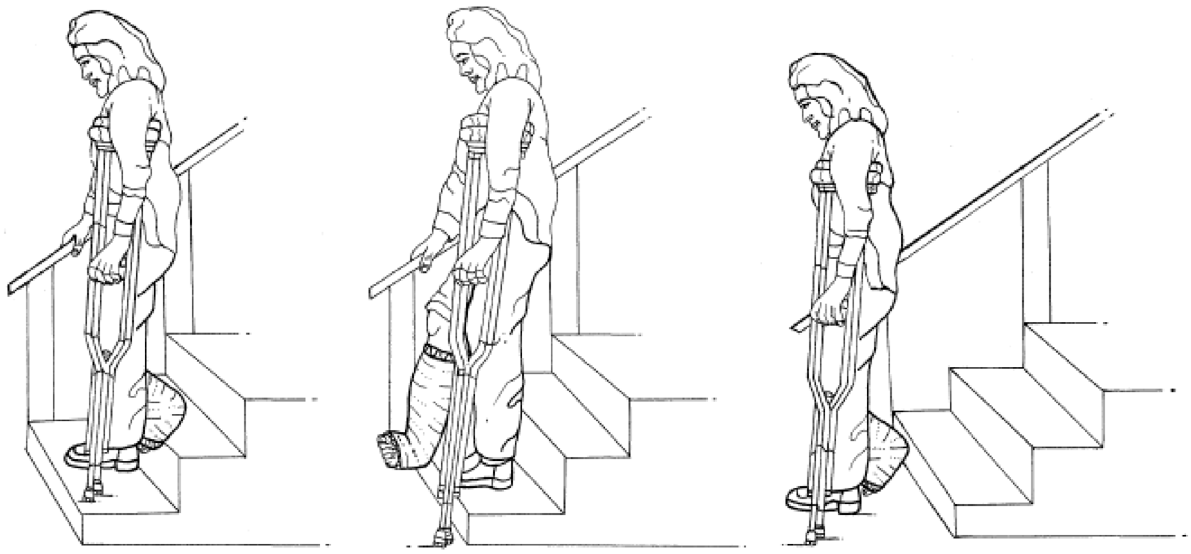


FIGURE 42 *(above, left)* walking up stairs with a banister: If a banister is present and a patient is nonweight bearing, the patient uses one or two crutches together on the uninvolved side and holds the banister with the hand on the same side as the fracture.
FIGURE 43 *(above, middle)* The uninvolved extremity is placed on the step above while the patient pulls the body up using the banister.
FIGURE 44 *(above, right)* The fractured limb and crutches are then advanced and brought up a step.

To descend stairs, the patient holds the banister with the hand on the same side as the fracture, and the fractured limb is placed on the step below concomitant with the crutches. The uninvolved extremity is then brought down to the step (Figures 45, 46, and 47).



In FIGURE 45 *(above, left)* Descending stairs using a banister. To descend stairs, the patient holds the banister with the hand on the same side as the fracture and uses one or two cmtches together on the uninvolved side.
FIGURE 46 *(above, middle)* The crutches and the fractured limb are placed simultaneously on the step below.
FIGURE 47*(above, right)* The uninvolved extremity is brought down to the step.
general, patients with good balance and coordination prefer using two crutches.

Transfers

The patient's weight-bearing status also affects transfers, or changes in position or location. Transfer techniques include stand-pivot, ambulatory, and seated transfers.

Stand-Pivot Transfers

A pivot transfer is designed to keep the fractured limb non-weight bearing to avoid transmitting a large amount of torque to the fracture site. The patient stands on the uninvolved lower extremity and pivots with the use of an assistive device (crutches or a 'walker) without bearing weight on the fractured limb.

Ambulatory Transfers

During ambulatory transfers, the patient is ftilly weight bearing on the uninvolved extremity and toe touch or partially weight bearing on the fractured extremity. The patient does not pivot during transfer, but does require the use of an assistive device to bear partial weight on a fractured limb.

Seated Transfers

Seated transfers do not require lower extremity weight bearing. They are used when neither lower extremity is fully weight bearing. This occurs with bilateral lower extremity fractures or pelvic fractures after multiple trauma. To perform a seated transfer, the patient supports his or her body weight with the upper extremities, while sliding the buttocks from one surface (e.g., a bed) to another (e.g., a wheelchair).

Bone healing

Healing can take place either primarily, in the presence of a rigid fixation, or secondarily in the absence of a rigid fixation.

***Primary* bone healing** occurs with direct and intimate contact between the fracture fragments. The new bone grows directly across the compressed bone ends to unite the fracture. Primary cortical bone healing is very slow and cannot bridge fracture gaps. There is no radiographic evidence of a bridging callus with this mode of healing. It usually occurs approximately 2 weeks from the time of injury. This is the only method of fracture healing with rigid compression fixation of the fracture. Rigid fixation requires direct cortical contact and an intact intramedullary vasculature. The healing process depends primarily on osteoclastic resorption of bone followed by osteoblastic new bone formation **(Figure 48)**

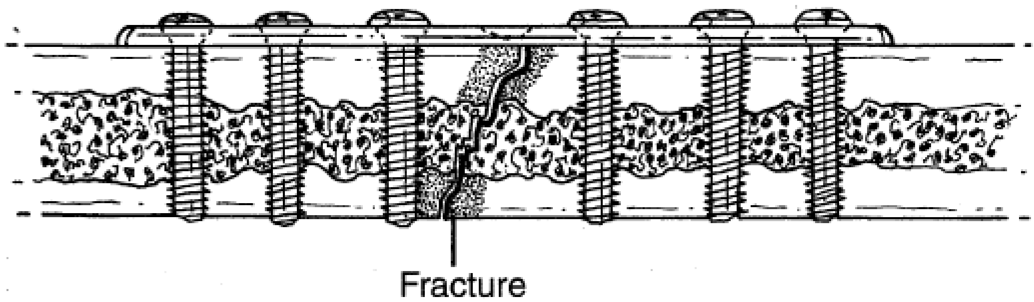


FIGURE -48 Rigid compression fixation of a fracture with a plate.

There is direct cortical contact and an intact intramedullary vasculature, which allows primary bone healing. The new bone grows directly across the compressed bone ends to unite the fracture.

Secondary bone healing denotes mineralization and bony replacement of a cartilage matrix with a characteristic radiographic appearance of callus formation. The greater the motion at the fracture site, the greater will be the quantity of callus. This external bridging callus adds stability to the fracture site by increasing the bony width. This occurs with casting and external fixation as well as intramedullary rodding of the fracture. This is the most common type of bone healing.

The three main stages of fracture healing as described by Cruess and Dumont are (a) the inflammatory phase (10%), (b) the reparative phase (40%), and (c) the remodeling phase (70%). These phases overlap, and events that occur mainly in one phase may begin in an earlier phase.

The length of each stage varies depending on the location and severity of the fracture, associated injuries, and the age of the patient. The inflammatory phase lasts approximately 1 to 2 weeks. Initially, a fracture incites an inflammatory reaction. The increased vascularity that encompasses a fracture allows for the formation of a fracture hematoma, which is soon invaded by inflammatory cells, including neutrophils, macrophages, and phagocytes. These cells, including the osteoclasts, function to clear necrotic tissue, preparing the ground for the reparative phase. Radiographically, the fracture line may become more visible as the necrotic material is removed (Figure 49).

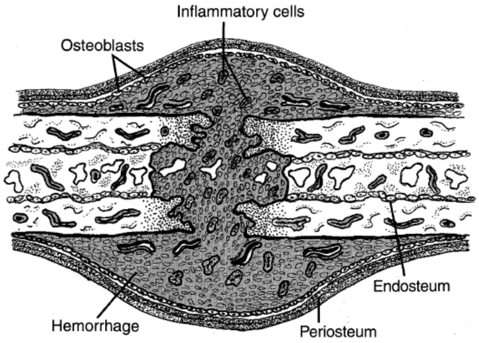


FIGURE 49 inflammatory phase of secondary bone healing. A fracture hematoma has been invaded by cells and the periosteum is elevated. Osteoblasts begin to absorb necrotic bone. This phase lasts for 1 to 2 weeks.

The reparative phase usually lasts several months. This phase is characterized by differentiation of pluripotential mesenchymal cells. The fracture hematoma is then invaded by chondroblasts and fibroblasts, which lay down the matrix for the callus. Initially, a soft callus is formed, composed mainly of fibrous tissue and cartilage with small amounts of bone. Osteoblasts are then responsible for the mineralization of this soft callus, converting it into a hard callus of woven bone and increasing the stability of the fracture. This type of bone is immature and weak in torque and therefore cannot be stressed. Delayed union and nonunion result from errors in this phase of bone healing. The completion of the reparative phase is indicated by fracture stability. Radiographically, the fracture line begins to disappear **(Figures 50 and 51)**

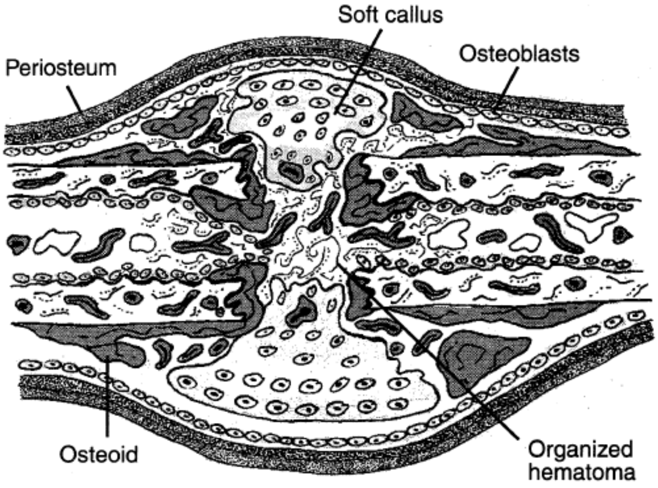


***FIGURE* 50** Soft callus formation of the reparative phase of bone healing. The hematoma begins to organize and is invaded by chondroblasts and fibroblasts that lay down the matrix for callus formation. The soft callus is composed mainly of fibrous tissue and cartilage with small amounts of bone.

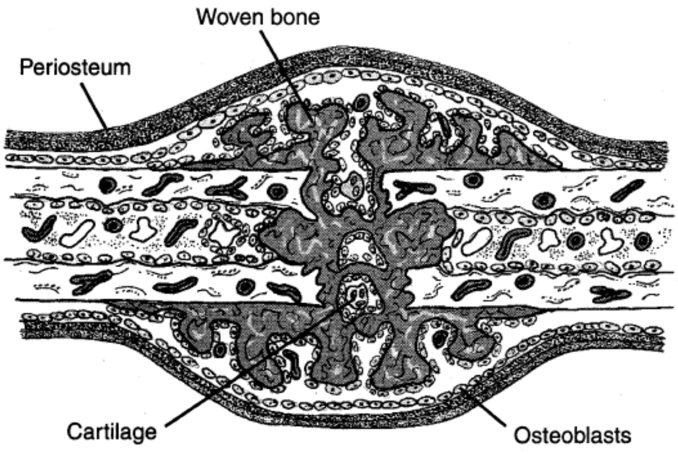


Figure 51 Hard callus formation, reparative phase. Osteoblasts are responsible for mineralization of the soft callus, converting it to hard callus, the woven bone. The soft callus is replaced by a mechanically more resistant one. This phase lasts for several months.

The *remodeling phase*, which requires months to years for completion, consists of osteoblastic and osteoclastic activities that result in replacement of the immature, disorganized woven bone with a mature, organized lamellar bone that adds further stability to the fracture site. Over time, the medullary canal gradually reforms. There is resorption of bone from the

convex surfaces and new formation on the concave surfaces. This process allows for some correction of angular deformities but not rotational deformities. Radiographically, the fracture usually is no longer visualized **(Figure 52 and Table 3).** The endosteum accounts for approximately two thirds of the blood supply to the bone; the remainder is provided by the periosteum. It is therefore not surprising that open or severely comminuted fractures with significant periosteal stripping have difficulties with bony union. Reaming of the medullary canal during the insertion of an intramedullary rod disrupts the

endosteal blood supply, requiring weeks for its regeneration, if not longer. Injuries to the soft tissue envelope deprive the fracture fragments of blood and alter bone healing. The soft tissue envelope surrounding the bone absorbs some of the force transmitted to the bone during the initial insult. It also protects the bone from desiccation and provides a vascular supply for a healing fracture. The metaphyseal area of bone has no periosteal cambium layer. As a result, less exuberant callus formation is visualized radiographically in this region compared with the diaphyseal areas. The method of fracture treatment used determines to some extent the mode of bone healing. In general, stress-sharing devices such as casts, intramedullary

nails, and external fixators do not provide rigid fixation at the fracture site. Therefore, secondary bone healing with callus formation may be expected in those cases. With a statically locked intramedullary nail, more rigidity is achieved, and callus formation may not be as abundant. Stress-shielding devices such as compression plates result in rigid fixation at the fracture site in the absence of significant comminution. These devices lead to a primary mode of bone healing and a lack of radiographically visible callus.

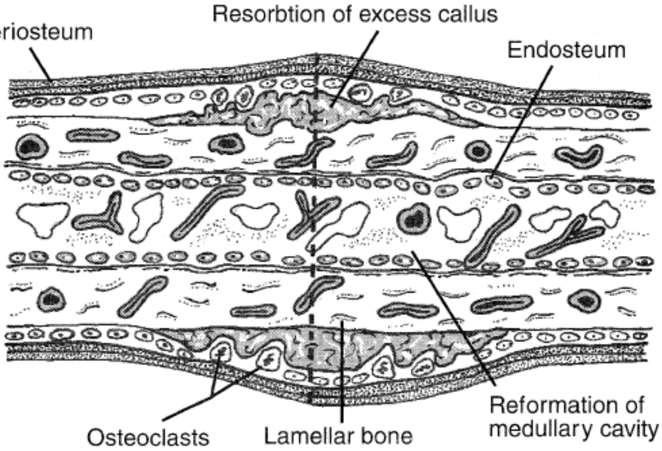


FIGURE 5 2 Remodeling phase. Excess callus is resorbed. Osteoblastic and osteoclastic activity result in replacement of immature, disorganized woven bone with more organized lamellar bone, adding stability to the fracture site. The medullary canal reforms. Remodeling requires months to years for completion.

TABLE 3 Phases of Bone Healing

Phase	Time	Healing Phase	Percentage of Main Activity	Strength (0–4)*	Function
Inflammatory	Days	10%	Débridement of bone Inflammatory reaction and osteoclastic activity Release of growth factor Chemotaxis of blood vessels and bone cells	0	Totally restricted
Reparative	Weeks to months	40%	Soft callus Fibrous tissue Cartilage and small amounts of bone	1–2	Restricted
			Hard callus Woven bone Deformable tissue is replaced by mechanically more resistant one	3	Improved
Remodeling	Years	70%	Lamellar bone formation Resorption of excess callus Osteoblastic and osteoclastic activity Reformation of medullary canal	4	Near normal

*Strength 0–4, 4 being the strongest.

Determining When a Fracture Has Healed

Clinical judgment, radiographic evaluation, and historical knowledge of how long each fracture takes to heal remain the mainstay for evaluating fracture healing. The goal of fracture treatment is for the fracture to heal so that the mechanical function of the bone-its ability to withstand weight bearing and provide joint motion-is restored. The race is between fracture healing and negative sequelae such as loss of fracture reduction, tissue stiffness, and muscle wasting. The clinical judgment that a fracture has healed is based on the combination of the patient's symptoms and physical findings over time, which usually are good indicators of the status of healing.

The clinical history should focus on the presence, absence, or diminution of the patient's pain as well as the nature of that pain, especially as it relates to weight bearing, lifting, or range of motion. On examination, the clinician should evaluate the fracture site for tenderness and motion; the absence of pain, tenderness, and motion indicates a healed fracture. The absence of motion in the presence of tenderness indicates a healing fracture, whereas the presence of motion with or without tenderness indicates a fracture that has not healed. The patient must be assessed during functional activities, including weight bearing, to see if any pain, discomfort, or instability occurs. The patient may have local pain secondary to stiffness and disuse, despite a healed fracture.

Radiographic evaluation focuses on callus formation as well as the blurring or disappearance of the fracture line on ubsequent x-ray films. A fracture is considered healed when there is progressive callus formation as occurs with secondary bone healing, with blurring and disappearance of the fracture line. These changes, along with the clinical findings, provide the clinician with sufficient information to assess the stability of the fracture in most patients (Figures 53,54,55,56,57 and 58)



FIGURE 53 *(above, left)* Healed fracture of the humeral diaphysis. Bridging callus has obliterated most of the fracture line. The medullary canal and callus will remodel with time.

FIGURE 54 *(above, middle)* Healed fracture of the second metatarsal with large amounts of callus formation. The fracture is in the remodeling stage. The patient may bear weight.
FIGURE 55 *(above, right)* Fracture of the fifth metacarpal diaphysis with visible callus formation.

FIGURE 56 Colles' fracture with callus formation.

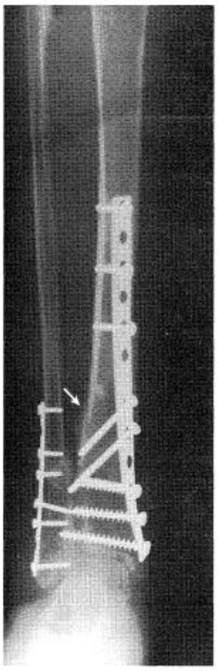


FIGURE 57 ***(left)*** *Fracture* of the distal tibia and plafond with callus formation.
FIGURE 58(right*)* Fracture of the tibial shaft with callus formation

Historical knowledge plays a major role in fracture management. Each fracture has a general time line for healing and, with experience; a clinician can adequately assess the progression of the fracture. For example, a distal radius fracture is expected to heal within 6 to 8 weeks, whereas a mid-diaphyseal tibial fracture might require more than 3 months.

The location of the fracture also affects the type of bony union achieved and aids the physician in predicting the amount of callus response. Stable metaphyseal fractures tend to heal with little visible external callus because of stable interdigitation and impaction of the fracture fragments as well as minimal periosteal presence (see Figure 59).

FIGURE 59 Impacted proximal humeral fracture, also considered a one part fracture (Neer classification). A two-part fracture involves either I cm of separation or 45 degrees of angulation of the fracture fragments.

In contrast, diaphyseal fractures, if stabilized adequately, unite with external callus secondary to lack of impaction, the presence of a gap that is bridged by new bone formation, and the presence of adequate periosteal coverage. Intracapsular fractures (e.g., fracture of femoral neck)-as opposed to extracapsular fractures (e.g., intertrochanteric fracture of femur)-tend to heal with less callus formation because of the lack of periosteum and the presence of synovial fluid (see Figures 60 and 61).

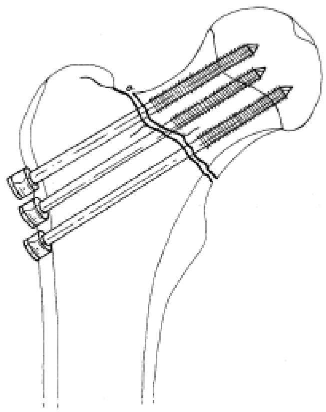


FIGURE 60 Multiple parallel cannulated screws for internal fixation of a Garden·s type I fracture. Fractures that are adequately reduced in patients younger than 65 years of age are treated with internal fixation *in situ.*

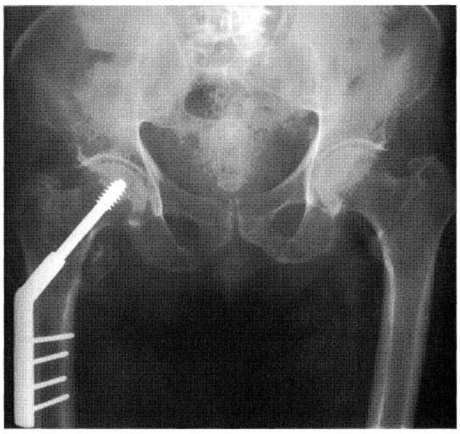


FIGURE 61 Sliding hip screw nail provides internal fixation and maintenance of reduction of an intertrochanteric fracture with restoration of length. The neck shaft angle has been restored to approximately 127 degrees. This fixation is stable; early
weight bearing may begin.

The type of fixation also affects fracture healing. Rigidly fixed fractures have less radiographic evidence of callus because they have less motion, which is necessary to induce callus formation (see Figur62).

FIGURE 62 Both-bones fracture of the forearm treated with compression plate fixation of both the radius and the ulna. This fixation restores the anatomic alignment of the radius and ulna and the radial bow, and allows early range of motion of the elbow, forearm, and wrist.
.

The following suggest complete healing:

absence of pain on weight-bearing, lifting or movement;

no tenderness on palpation at the fracture site;

blurring or disappearance of the fracture line on X-ray;

full or near full functional ability

Time for a fracture to unite

The time it takes for a fracture to unite depends on a number of factors.

Type of bone. Cancellous bone heals more quickly than compact bone. Healing of long bones depends on their size so that bones of the upper limb unite earlier (3–12 weeks) than do those of the lower limb (12–18 weeks).

Revascularisation of devitalised bone and soft tissues adjacent to the fracture site.

The mechanical environment of the fracture

Classification of the fracture. It is easier to obtain good apposition of bone ends with some fractures than with others. This may depend on the initial position of the fragments before reduction and the effect of muscle pull on the fragments.

Blood supply. Adequate blood supply is essential for normal healing to take place. Certain fractures can be notoriously slow to heal (e.g. fractures of the lower third of tibia). This part of the bone has a poor blood supply owing to the fact that under normal circumstances it does not require one as there is little muscle bulk here, therefore little demand for nutrients and oxygen.

Fixation. Adequate fixation prevents impairment of the blood supply which may be caused by movement of the fragments. It also maintains the reduction thus preventing deformity and consequent loss of function. Interestingly, if a fracture is rigidly immobilised, the stimulus for callus to form is lost, so a small amount of movement at a fracture site actually encourages fracture healing.

Age. Union of a fracture is quicker in children and consolidation may occur at between 4 and 6 weeks. Age makes little difference to union in adults unless there is accompanying pathology.

Drugs. It has been suggested that certain *drugs* such as non-steroidal anti-inflammatory drugs may interfere with fracture healing; however, evidence remains inconclusive.

Smoking. There are increased rates of delayed union and non-union in people who smoke who have sustained open tibial fractures.

Ultrasound. Recent work has suggested that low intensity ultrasound may accelerate fracture healing.

Another factor is the extent of overall trauma. The amount of comminution and soft tissue trauma, as well as open injuries, guide the clinician to expect an extended period of fracture healing. Age also plays a role in fracture union: fractures in older patients heal more slowly than those in children. One difficult task is identifying a delayed union or nonunion. Only by knowing the type and severity of the fracture can the clinician truly assess if a fracture is healing in a timely fashion. Sometimes the patient's clinical findings do not correlate well with the radiographic findings. For example, a lack of pain or tenderness combined with the radiologic persistence of a fracture line is suggestive of a fibrous union. In such cases, the use of other modalities such as bone scans, plain and computed tomography, and magnetic resonance imaging might play a role in determining if a fracture has healed. In most cases, the clinician can assess the fracture's healing progression simply by relying on good clinical judgment, sound radiographic evidence, and knowledge of fracture management.

Weight bearing post fractures

Definition:

Weight bearing (WB) is defined as the percentage of body weight carried out by the limbs either during exercises or during normal functional activities.

The concept of weight bearing in traumatized patients depends primarily on:

1. Broken bone
2. Type of fixation (load or stress sharing and load or stress shielding)
3. Stability of fracture post fixation

N.B. unstable fractures permit WB if type of fixation offering good stability to the broken bones.

Mechanics of fracture fixations:

The aim of fracture fixation is to stabilize and support the fractured bone to facilitate the process of fracture healing. Loss of appropriate stabilization is resulted from either inappropriate fracture fixation or nature of the fractured bone (e.g. comminuted fractures).

All types of fracture fixations can be divided from the biomechanical point of view into:

1. Load sharing (stress sharing) devices.
2. Load shielding (stress shielding) devices.

Load sharing devices characterized by its capability to stress bone during WB process and hence its name, it shares the weight of body between it and bone. The body weight stresses the site of fracture and develops micro- motion which helps to facilitate healing process and accelerates fracture repair. The type of healing observed was secondary bone healing. Examples of load sharing devices include: intra-medullary nailing, ilizarov extemal fixation, cast, and DHS.

Load shielding devices prevents bone from bearing any weight, hence its name it shields the bone from forces of body weight. No micro-motion observed with these types of fixations. The type of healing observed was primary bone healing. Examples of load shielding devices include: plate and screw fixations, static locked intra-medullary nail, and all types of external fixations except ilizarov.

Important Keys

1. Load sharing devices permit early weight bearing on the affected extremity provided that the fracture was stabilized will.
2. Load shielding devices permit late weight bearing after radiological union to avoid failure of fixation.

Types of weight bearing post fractures:

1. Non weight bearing (NWB)
2. Toe touch or Touchdown weight bearing (TDWB)
3. Partial weight bearing (PWB)
4. As tolerated weight bearing
5. Full weight bearing (FWB)

1. None weight bearing (NWB)

Definition:

The patient with NWB ambulates with the aid of assistive devices as walker or bilateral crutches and the affected lower limb is completely off the ground. In another word, the non-affected lower limb bear all body weight by the aid of upper limb using walking aids.

Indication:

NWB is indicated in cases with unstable fractures or post rigid load shielding devices.

2. Toe touch or Touchdown weight bearing (TDWB)

Definition:

It is exactly the same as NWB, i.e. the affected lower limb deprived from body weight but it was in touch with the ground. The toes only or all foot in touch with the ground but without bearing any body weight.

Indication:

It was indicated in the same cases as in NWB in addition to the following:

1. Cases suffering from weakness in muscle of the affected limb i.e. their legs couldn't be hanged for the time of walking.
2. Patient indicated for proprioceptive exercises hence the foot contact with the ground help to improve its proprioceptive sense.
3. TDWB was less stressful to the cardiovascular system than NWB ambulation (suitable for elderly)

3. Partial weight bearing (PWB)

Definition:

In PWB, the patient starts to bear body weight by the affected limb but in graded manner. In another word, certain percent of body weight (e.g. 5-10-15%) only allowed to be bearded on the affected limb. Here, the physiotherapist must learn the patient by the aid of scale how to bear the target weight before initiation of gait training.

Indication:

It was indicated in cases deprived from WB for long period of time as with load shielding devices. At first when ambulation is permitted after healing, it was in the form of PWB and then graduated to reach FWB.

4. **As tolerated weight bearing**

Definition:

In this type of weight bearing, the patient is asked to bear weight on the affected limb as he can tolerates, i.e. as much as he can.

Indication:

This type of WB is indicated in cases of stable fractures and with fractures fixed with load sharing devices.

5. **Full weight bearing (FWB)**

Definition:

Full weight bearing represents the final stage of WB in which all body weight is permitted to be bearded on the affected limb without any limitation with and without walking aids

Indication:

It represents the success of the process of WB training of all the previous four categories.

Intra-articular Fracture

Definition:

Is a fracture caused by a high energy trauma which produces a fracture line that travels the articular surfaces of the joints, resulting in some degree of cartilage damage, usually the # line starts extra-articular and extends to the articular surface. It can be associated with soft tissues injuries as joint capsule rupture, ligamentous injuries, meniscal injuries and joint dislocations.

Site:

Metaphysis (cancellous bone) around joints {mention the function of spongy bone near joints?

Clinical presentation:

Patient may present with joint swelling, pain, and difficulty of walking after an injury. Generally an effusion is present which is resulted by hemarthrosis, other exam findings may be nonspecific and include tenderness near the fracture site or decreased range of motion.

Mechanism of injury:

Direct trauma falling on elbow # olecranon, # humeral condyles
Indirect trauma =→ falling on side =→ # neck of femur

=→falling on outstretched hand =→ # neck of humerus

=→ Excessive uncontrolled foot motion =→ pott's #

Expected time of healing:

Complications

1. Loss of joint range of motion (ROM): due to prolonged period of immobilization and fibers formation at joint capsules. active movements of neighboring joints. ROM ex's to the affected joint as early as the condition allows.
2. *post traumatic arthritic* changes of articular surfaces due to displacement or mal-union so it is necessary to maintain good anatomical reduction of intra-articular fracture. =→ delay WB and vigorous motion near # site till radiological union.
3. *joint instability* due to ligamentous injuries, e.g. tibial plateau # + medial collateral or ACL surgical repair avoid excessive stress on injured ligament.
4. *A-Nerve injury*, e.g. Ulnar nerve trauma in medial humeral epicondyle #.
5. *Avascular necrosis*, which is a bone death and shrinking due to cut of the blood supply secondary to # line, e.g. # neck of femur, # neck of hummers, # scaphoid waist.=→ joint surface replacement.
6. *Healing problems* (non-union or delayed union) secondary to poor blood supply or washing of # hematoma by synovial fluid {mention the function of synovial fluid? use of sharing device to enhance healing.

7. *Post-traumatic ossification:* spreading of the callus formation to nearby soft tissue structures, e.g. # around the elbow, # around the knee.

Long term problems

Include presence of a palpable or visible bony prominence, deformity, numbness, weakness, reflex sympathetic dystrophy and others. Less likely problems include re-fracture, compression neuropathy and tendon rupture.

Treatment:

The options for intra-articular # are limited and depend on the extension of the injury.

Criteria for conservative treatment:

- No associated soft tissue injury.(nerve, artery, or tendons)
- No intra-articular structural injury.(meniscus, capsule)
- No obvious deformity (valgus - varus or rotation)
- No large joint surface depression.
- Sever comminuted # (complete joint surface destruction)^-^ closed arthrodesis
- Minimally displaced #.

Criteria for operative treatment:

Nearly all intra-articular #s are treated by this method to regain anatomical reduction and rigid fixation to avoid farther complications.

Methods of fixations:

Principles of rehabilitation for intra-articular #:

i.ROM

– In most intra-articular #s the affected joint is fixed in cast or splints even after internal fixations for 4-6 weeks according to # stability. While the nearby joints are moved through its available ROM unless this affects the # site.
– After removal of the splint, begin AROM for the affected joint uni-planer with avoidance of rotatory component and with no stress on hardware.
– At 8-10 weeks, begin auto passive mobilization and self-stretch.

ii.Muscle power

- Through the period of fixation static contractions around the affected joint is the option. While the muscles away from the joint but has attachment to # line AFROM ex's is the option till healing, e.g. gastrocnemius in femoral condylar #, brachioradialis in coil's #.
- At 4-6 weeks we can start isometric contraction to the muscle group crossing the joint (crossing the #). By the end of this period start isometric contraction to the avoidance muscles group.
    - At 8-10 weeks begins PRE.

iii. WB

- All intra-articular # will stay NWB for 10-12 weeks to avoid stress on the hardware and avoid any displacement.
- In some stable #s we can begin TDWB / PWB at 8th week,

iv. ***Gait***

- *3-point gait (orthopedic gait) for NWB.*
- *Modified 3-point gait for TD WB/PWB*

v. ***Functional activities***

- Limited joint is avoided in heavy ADL in UL, while in LL is completely avoided in all ADL.

Shaft of long bone fracture

Site: At diaphysis (long bone between two physis)

Mechanism of injury:

High energy trauma: (direct) transverse or comminuted (angulatory force)

Low energy trauma: (indirect) spiral or oblique (twisting or rotatory force) and make fracture at weak point of the long bone

...Fatigue fracture: at shaft of the tibia at the long distance runner &jump dancing (it happen between upper and middle third) and at the military, fracture happens at the shaft of the metatarsal bone

Shape of the fracture:

Transverse # (and may be just fair line as with fatigue fracture),Spiral ,oblique , butterfly, and comminuted #

N.B: the most staple fracture is the transverse fracture including fatigue # and the least staple # is butterfly and comminuted fracture.

N.B: long bone fracture most commonly open fracture especially tibia because it is subcutaneous

Time of healing:

Upper limb → 8-12 week

Lower limb →10-16 week

Effect of muscle on bone displacement:

The displacement of the fragment of the fracture affected by the nearby insertion of the muscle

Example:

Proximal shaft of humerus:

If the fracture above pectoralis major muscle→ the proximal fragment displace in abduction and external rotation direction

If fracture site below the pectoralis →the proximal fragment displaces in adduction direction.

If fracture site below the deltoid →the proximal fragment displaces in abduction direction.

Treatment

May be conservative and may be operative

Conservative:

For stable, undisplaced fracture use cast and the cast length according to level of the fracture and stability of the fracture

Example:

Femur →Hip Spica (rare to use cast)

Tibia→long leg cast with 20°flexion of knee joint to avoid rotational force on fracture site then replaced by short leg cast

Upper humerus →afunctional brace, no cast to avoid increase tension load on fracture site

Both bone radius and ulna →long arm cast for non-displaced fracture then replaced by short arm cast 4-6 week

Isolated ulna # → short arm cast.

Surgical:

Intramedullary nail:

Most commonly used for long bone fracture because

- allow early healing
- It allow early weight bearing
- It used with pathological bone fracture

N.B. it can't be used with radius because it's bowing

It can be used static or dynamic (locked or unlocked) according to stability of the fracture

Most commonly used dynamic locked

EX. TV fracture-^ unlocked

Piate and screws.

Best for shaft fracture with peri-articular or intra-articular extension

*stress shielding

* Not used with the weak bone

External skeletal fixation

*Used when immediate operative procedure is not feasible.

*Used with contaminated and unstable fracture.

*Used with sever tissue loss or thermal bum.

Rehabilitation

after conservative treatment

***ROM**

AROM / AAROM for the joint above and joint below the cast ,PROM after complete healing

* strength ms:

Static & isometric inside cast and isotonic after removal of cast
After internal and external fixation
*ROM:
AROM/AAROM→ for all nearby joints.
PROM → after complete healing of the fracture.
*Ms strength:

Begin with static/isometric (gentle) then isotonic. At 4-6 week begin with gentle resistance then progress after complete healing

Principles of Management: Period of Immobilization

Impairments, Activity Limitations, and Participation Restrictions:

Initially, inflammation and swelling

Progressive muscle atrophy, contracture formation, cartilage degeneration, and decreased circulation in the immobilized area

Potential overall body weakening if confined to bed

Limited activity and restricted participation in ADLs, IADLs, and work imposed by the fracture site and method of immobilization used

Plan of Care	Intervention
1. Educate the patient.	1. Teach functional adaptations. Teach safe ambulation, bed mobility.
2. Decrease effects of inflammation during acute period.	2. Ice, elevation
3. Decrease effects of immobilization.	3. Intermittent muscle setting. Active ROM to joints above and below immobilized region.
4. If patient is confined to bed, maintain strength and ROM in major muscle groups.	4. Resistive exercises to major muscle groups not immobilized, especially in preparation for future ambulation

Principles of Management: Period of postimmobilization

Impairments:

Pain with movement, which progressively decreases

Decreased ROM

Decreased joint play

Scar tissue adhesions

Decreased strength and endurance

Plan of Care	Interventions
1. Educate the patient.	1. Inform patient of limitations until fracture site is radiologically healed. Teach home exercises that reinforce interventions.
2. Provide protection until radiologically healed.	2. Use partial weight bearing in lower extremity and nonstressful activities in the upper extremity.
3. Initiate active exercises.	3. Active ROM, gentle multiangle isometrics
4. Increase joint and soft tissue mobility.	4. Initiate joint play stretching techniques (using grades III and IV) with the force applied proximal to the healing fracture site. For muscle stretching, apply the force proximal to the healing fracture site until radiologically healed.
5. Increase strength and muscle endurance.	5. As the ROM increases and the bone heals, initiate resistive and repetitive exercises.
6. Improve cardiorespiratory fitness.	6. Initiate safe aerobic exercises that do not stress the fracture site until it is healed.

PRECAUTIONS: No stretch or resistive forces distal to the fracture site until the bone is radiologically healed. No excessive joint compression or shear for several weeks after the period of immobilization. Use protected weight bearing until the site is radiologically healed.