3.5 EMG Bio Feedback Instrumentation

EMG (Electromyography) biofeedback is a technique used to measure and monitor the electrical activity of muscles. This information can then be used to train individuals to control their muscle tension and relaxation.

Instrumentation for EMG biofeedback typically involves the following components:

1. **Electrodes:** These are small, adhesive patches placed on the skin over the muscles being monitored. They detect the electrical signals produced by muscle activity.
2. **Amplifier:** This device amplifies the weak electrical signals from the electrodes to a level that can be processed by the biofeedback device.
3. **Biofeedback Device:** This is a computer or specialized device that processes the amplified EMG signals and provides feedback to the user. It can display the signals as a graph, sound, or other visual or auditory cues.

Types of Feedback:

- **Visual Feedback:** This is the most common type of feedback, where the EMG signals are displayed as a graph or a bar chart on a screen.
- **Auditory Feedback:** The EMG signals can be converted into sounds, such as beeps or tones, to provide feedback.
- **Tactile Feedback:** Some devices use vibration or other tactile sensations to provide feedback.

Applications of EMG Biofeedback:

- **Muscle Relaxation:** For conditions like tension headaches or muscle tension disorders.

- **Rehabilitation:** To improve muscle function after injury or surgery.
- **Athletic Performance:** To optimize muscle activation and coordination.
- **Pain Management:** To reduce pain associated with muscle tension.
- **Neurological Disorders:** To help manage conditions like cerebral palsy or stroke.

Benefits of EMG Biofeedback:

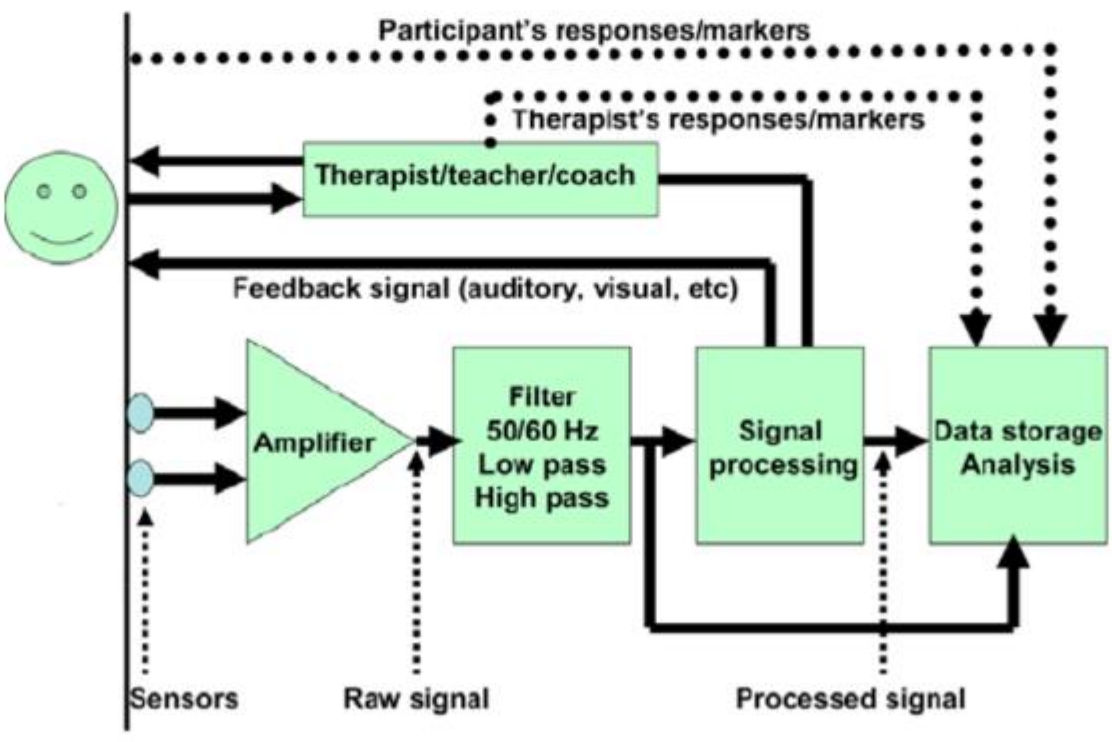
- **Non-invasive:** It does not involve any needles or injections.
- **Safe:** It is generally considered a safe and effective technique.
- **Effective:** It can help individuals learn to control their muscle tension and improve their overall well-being.

Biofeedback as a component of treatment

- It is important at the outset to emphasize that biofeedback is not at its most effective when used as a treatment in its own right, but should be integrated with other therapeutic interventions.
- It acts as an enhancer of the therapy, enabling the patient (and the therapist) to make more effective and rapid progress towards the rehabilitation goal. Furthermore, it is useful in that it helps the patient to reduce their reliance on the therapist and become more reliant on their own performance.
- Clearly this is not fully achieved if the patient becomes reliant on the machine instead of the therapist! It can be used effectively to enable the patient to take some control or ownership over their rehabilitation - empowerment is a often used phrase in this context.
- The key to success of biofeedback in rehabilitation is to use the device as an adjunct to therapy, to enable the patient to gain control without reliance on the therapist, and once gained, to maintain control without either the therapist or the machine. This approach is entirely in keeping with the general aim of modern physiotherapy, and the technology is an aid to the outcome, not a magical solution.

EMG biofeedback used

- to facilitate muscle contractions,
- to promote increased motor recruitment and improve poor mechanics,
- to regain neuromuscular control,
- to retrain joints' function after injury,
- to improve posture,
- to improve gait patterns,
- to improve balance
- to decrease muscle spasm,
- to calm down over-active muscles,
- to promote relaxation



❒ The Figure depicts a **Biofeedback System** used to monitor and control physiological responses. its components and working are as follows:

1. Sensors:

- These are devices that detect physiological signals from the participant, such as muscle activity, heart rate, skin conductance, etc.
- Examples include electromyography (EMG) sensors, electrocardiography (ECG) sensors, and skin conductance sensors.

2. Amplifier:

- The raw signals from the sensors are often very weak, so they need to be amplified to a level suitable for further processing.
- The amplifier boosts the signal's amplitude without significantly altering its shape.

3. Filter:

- The amplified signal is then passed through a filter to remove unwanted noise and interference.
- The filter typically includes:
  - ✓ A 50/60 Hz notch filter to eliminate power line interference.
  - ✓ A low-pass filter to remove high-frequency noise.
  - ✓ A high-pass filter to remove low-frequency drift.

4. Signal Processing:

- The filtered signal is further processed to extract relevant features, such as amplitude, frequency, and time-domain characteristics.
- This processing can involve techniques like Fourier transform, wavelet transform, or statistical analysis.

5. Data Storage and Analysis:

- The processed signal is stored for later analysis and visualization.

- ❖ Data analysis can reveal patterns and trends in the physiological responses, allowing for insights into the participant's state and response to interventions.

6. Feedback Signal:

- ❖ The processed signal can be used to generate a feedback signal, which is presented to the participant in various forms (auditory, visual, or tactile).
- ❖ This feedback helps the participant become aware of their physiological responses and learn to control them through biofeedback techniques.

7. Therapist/Teacher/Coach:

- ❖ A therapist, teacher, or coach can monitor the participant's progress and provide guidance and support during the biofeedback training sessions.
- ❖ They may also use the system to collect data for research or clinical purposes.

8. Participant's Responses/Markers:

- ❖ The participant's responses or markers (e.g., button presses, verbal feedback) can be recorded alongside the physiological data to correlate them and understand the participant's behavior and cognitive state.

Overall, the biofeedback system enables individuals to gain voluntary control over their physiological responses through real-time feedback and training. This can be beneficial for various applications, including stress management, pain management, athletic performance enhancement, and rehabilitation

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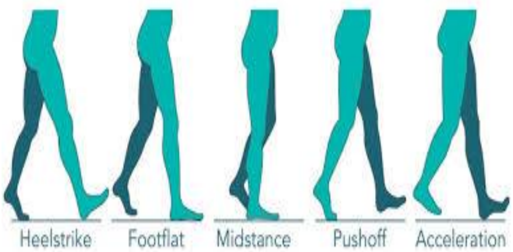
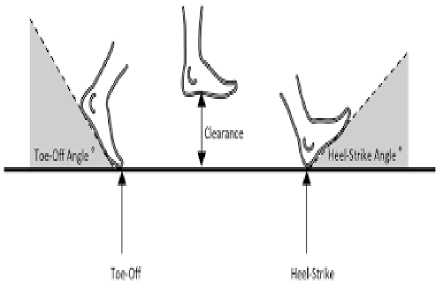
3.6 Static Measurement – Load Cell, Pedobarograph

3.6.1 Load Cell:

- **Load cells** are a fundamental tool in biomechanical research and clinical practice, providing accurate measurements of static forces. These devices are essential for understanding various physiological parameters, from muscle strength to joint forces.

Common Biomechanical Applications of Load Cells:





Gait Analysis:

- **Pressure Measurement:** Quantifying pressure distribution under feet during walking, running, or other activities.
- **Force Measurement:** Analyzing forces exerted by different muscles and joints during movement

Prosthetic and Orthotic Design:

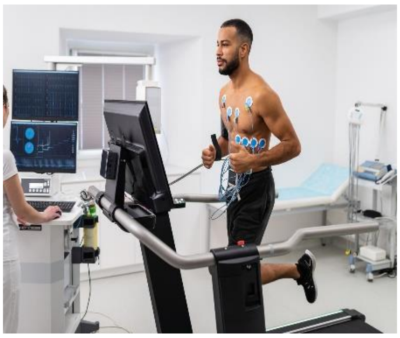
- **Force Measurement:** Evaluating the performance of prosthetics and orthotics to ensure proper fit and function.

- **Pressure Measurement:** Assessing pressure distribution on residual limbs to prevent skin ulcers.

Sports Biomechanics

- **Force Measurement:** Analyzing forces generated by athletes during various sports activities.

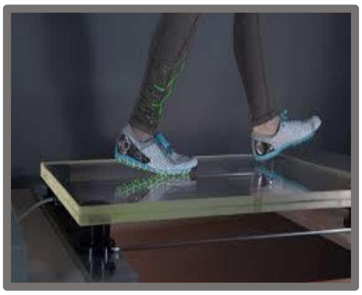
- **Pressure Measurement:** Studying pressure distribution in sports equipment like shoes and helmets.



Rehabilitation

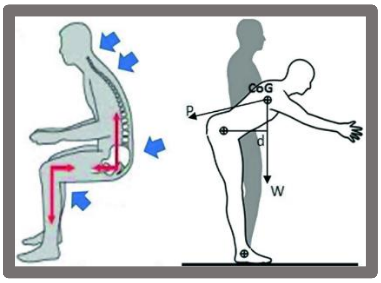
- **Force Measurement:** Monitoring progress during physical therapy and rehabilitation programs.
- **Pressure Measurement:** Assessing healing of wounds or skin grafts.

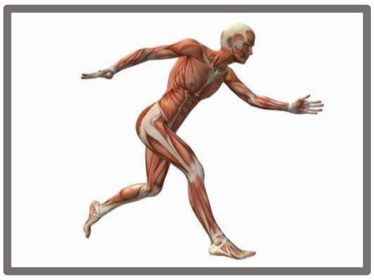




Occupational Biomechanics

- **Force Measurement:** Evaluating ergonomic factors in workplaces to prevent injuries.
- **Pressure Measurement:** Analyzing pressure distribution on hands and wrists during repetitive tasks.



Load Cells for Human Foot Pressure Measurement:

- Load cells are essential tools for measuring the distribution of pressure under the feet, providing valuable insights into gait analysis, footwear design, and clinical applications.

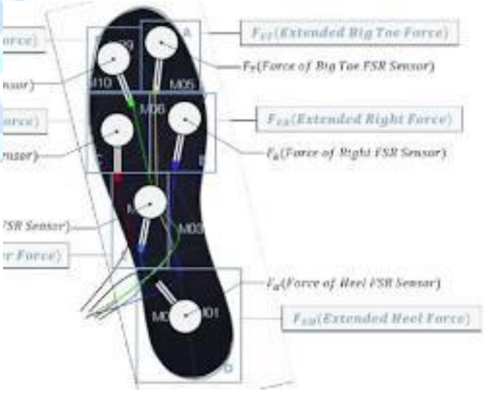
  Here are some common types of load cells used for human foot pressure measurement:

1. **Piezoresistive Load Cells**

- **Principle:** Based on the change in electrical resistance of a material when subjected to a force.
- **Construction:** Typically consist of a thin, flexible sensor layer embedded in a shoe insole.
- **Advantages:** High sensitivity, low cost, and flexibility.
- **Disadvantages:** May be susceptible to temperature fluctuations and long-term drift.

2. **Capacitive Load Cells**

- **Principle:** Measure changes in capacitance between two conductive plates when subjected to a force.
- **Construction:** Often constructed using flexible materials and can be integrated into shoe insoles.
- **Advantages:** High accuracy, wide measurement range, and good temperature stability.
- **Disadvantages:** More complex construction and potentially higher cost.

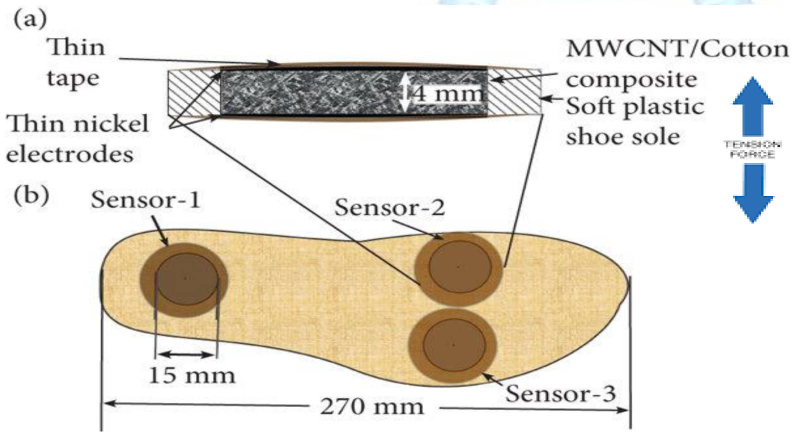


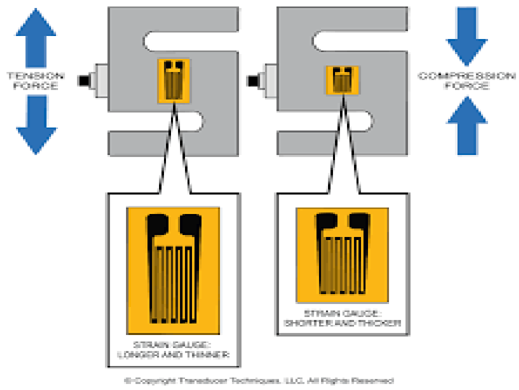
3. **Force-Sensitive Resistors (FSRs)**

- **Principle:** Measure changes in resistance when subjected to a force.
- **Construction:** Typically consist of a thin film material with conductive properties.
- **Advantages:** Simple construction, low cost, and flexibility.
- **Disadvantages:** Limited accuracy and sensitivity compared to other types of load cells.

4. Strain Gauge Load Cells

- **Principle:** Measure changes in resistance of a strain gauge when subjected to a force.
- **Construction:** Often integrated into shoe insoles or heel cups.
- **Advantages:** High accuracy, wide measurement range, and good temperature stability.
- **Disadvantages:** More complex construction and potentially higher cost.





Key factors to consider when selecting a load cell for human foot pressure measurement include:

- ❒ **Accuracy and resolution:** The ability to measure subtle changes in pressure.

- **Sensitivity:** The ability to detect low-intensity forces.
- **Durability:** The ability to withstand repeated use and environmental factors.
- **Comfort:** The load cell should not interfere with the wearer's comfort or gait.
- **Data acquisition:** The compatibility of the load cell with data acquisition systems and software.

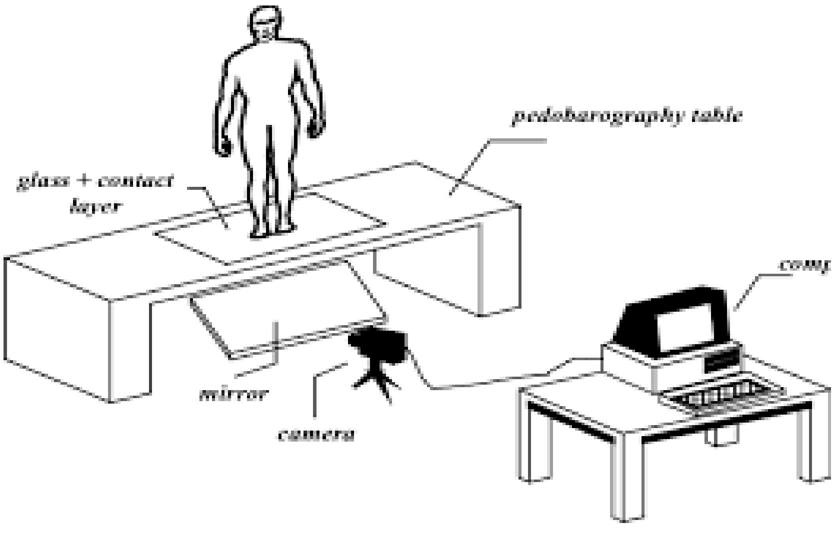
3.6.2 Pedobarograph:

- A pedobarograph is a device used to measure the pressure distribution under the feet. It is often used in the fields of podiatry, biomechanics, and sports medicine.

How does a pedobarograph work?

Pedobarographs typically consist of a platform or mat equipped with pressure sensors. When a person stands or walks on the platform, the sensors measure the pressure exerted by different parts of the foot. This data can then be analyzed to provide information about:

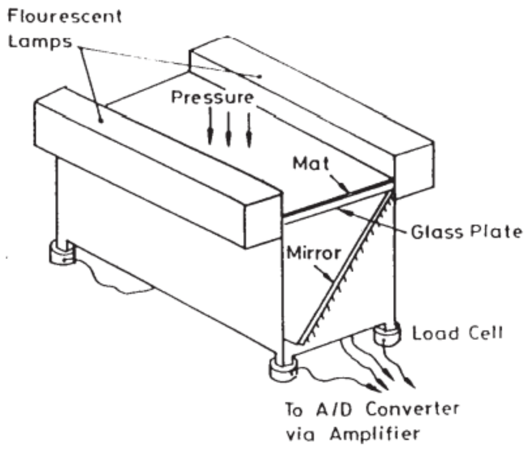
- **Pressure distribution:** How pressure is distributed across the foot
- **Peak pressure:** The maximum pressure exerted by the foot
- **Contact area:** The area of the foot in contact with the ground
- **Gait analysis:** The mechanics of walking or running



- **Pedobarography Table:** The person stands on a table with a transparent glass or contact layer on top.
- **Camera:** A camera is positioned below the table, capturing the light pattern that passes through the contact layer and the foot.
- **Mirror:** A mirror is often used to direct the light from the foot to the camera, allowing for a better view of the pressure distribution.
- **Computer:** The captured images are transmitted to a computer for processing and analysis.
- **Software:** Specialized software is used to analyze the images and generate pressure distribution maps, center of pressure (COP) trajectories, and other relevant parameters.

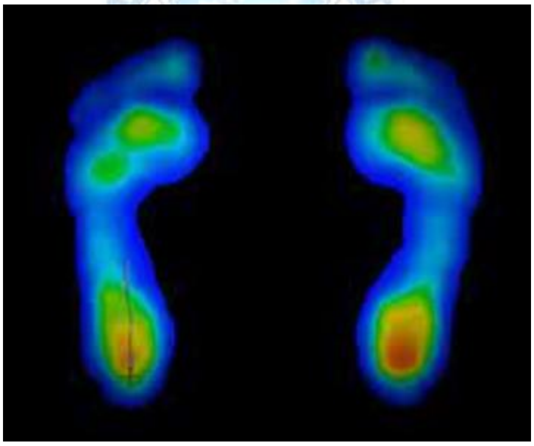
Working of Pedobarograph:

- **Light Source:** A light source illuminates the foot from below.
- **Transparent Layer:** The foot rests on a transparent layer (like glass or a specialized film).
- **Camera:** A camera captures the light that passes through the transparent layer and is modulated by the foot's pressure distribution.
- **Image Processing:** The captured image is processed to analyze the light intensity variations, which correspond to the pressure exerted by different parts of the foot.



Schematic diagram of the optical pedobarograph

- The pedobarograph consists of a thick glass plate mounted on a frame. The longitudinal sides of the glass plate are illuminated using fluorescent lamps.
- A thin deformable white plastic sheet is placed on top of the glass plate. In unloaded conditions, a glass-air interface exists as shown in Figure.
- Glass being denser than air, the condition of total internal reflection of light is satisfied when the angle of incidence for any ray of light exceeds the critical angle (42° for crown glass).
- Thus, all light from the fluorescent lamps undergoes total internal reflection in the glass plate. On application of load (pressure), the plastic sheet deforms proportionally, transforming the glass-air interface to a glass-plastic interface as shown in Figure.
- Since the refractive index of glass is lower than that of plastic, any ray striking the glass-plastic interface is scattered in all directions including out of the box. Since only reflected light intensity is recorded, a foot pressure image is generated.



Foot pressure image

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3.7 Dynamic Measurement – Velocity, Acceleration, GAIT, Limb position.

- Dynamic measurements in biomechanics involve quantifying the movement and forces involved in human movement.
- This data is essential for understanding how the body moves, how forces are generated and transmitted, and how these factors impact performance and injury risk.
- Dynamic measurement allows for real-time analysis of variables such as velocity, acceleration, joint angles, and muscle activation, which is essential for understanding functional movement patterns and assessing athletic performance, injury risk, and rehabilitation progress.

3.7.1 Degrees of Freedom:

- Degrees of freedom are the total ***number of independent movements*** needed to completely describe the position and orientation of a body in a given coordinate system.
- The musculoskeletal system has numerous degrees of freedom through which countless movements are accomplished.
- The number of degrees of freedom (DOF) in a ***human joint*** can range from ***one to six.***
- Dynamic measurements in biomechanics involve quantifying the movement and forces involved in human movement.
- This data is essential for understanding how the body moves, how forces are generated and transmitted, and how these factors impact performance and injury risk.
- Dynamic measurement allows for ***real-time analysis of variables*** such as velocity, acceleration, joint angles, and muscle activation, which is essential for

understanding functional movement patterns and assessing athletic performance, injury risk, and rehabilitation progress.

3.7.2 Velocity Mesurement:

- Velocity is a vector quantity, meaning it includes both the speed and direction of an object's movement.
- In biomechanics, velocity measurements help capture the movement patterns of body segments, allowing for detailed analysis of joint motion, segment interactions, and overall movement coordination.
- Dynamic velocity measurements are crucial for assessing changes in velocity (acceleration or deceleration) that occur in response to muscle forces and external loads (e.g., ground reaction forces).
- **Motion Capture Systems:**
  Infrared cameras and markers to capture the position of body segments. Velocity is derived by calculating the displacement of the markers over time, providing, 3-D data.
- **Inertial Measurement Units (IMUs)- Wearable sensors:**
  These wearable sensors (e.g., accelerometers and gyroscopes) measure acceleration and angular velocity, which can be integrated over time to estimate segment velocities.
- **Radar and Laser Systems:**
  These systems use Doppler effects to directly measure movement velocity. They are often used in sports and running biomechanics.
- **Force Plates:**
  When measuring activities like jumping, force plates capture ground reaction forces, which are used to calculate changes in velocity during movement (e.g., take off velocity, landing velocity).
- **High-Speed Video Analysis:**
  By tracking the displacement of body segments frame-by-frame, video analysis software allows for velocity calculations, often used in sports mechanics or gait analysis.

3.7.2.1 Motion Capture Systems:

By tracking the movement of markers or sensors attached to the body, these systems can accurately calculate the velocity of body segments and joint centers

1. Marker Tracking:

- Reflective markers are placed on specific anatomical landmarks of the body.
- Cameras capture the 3D positions of these markers over time

2. Data Processing:

- The captured marker positions are processed to reconstruct the 3D skeletal model of the subject.
- The software calculates the position of each joint center in 3D space at each time frame

3. Velocity Calculation:

Numerical Differentiation:

- The most common method to calculate velocity is by numerical differentiation of the position data.
- The difference in position between two consecutive frames is divided by the time interval between the frames to obtain the average velocity over that time interval.
- This process is repeated for each frame, resulting in a **time series of velocity values** for each joint center.

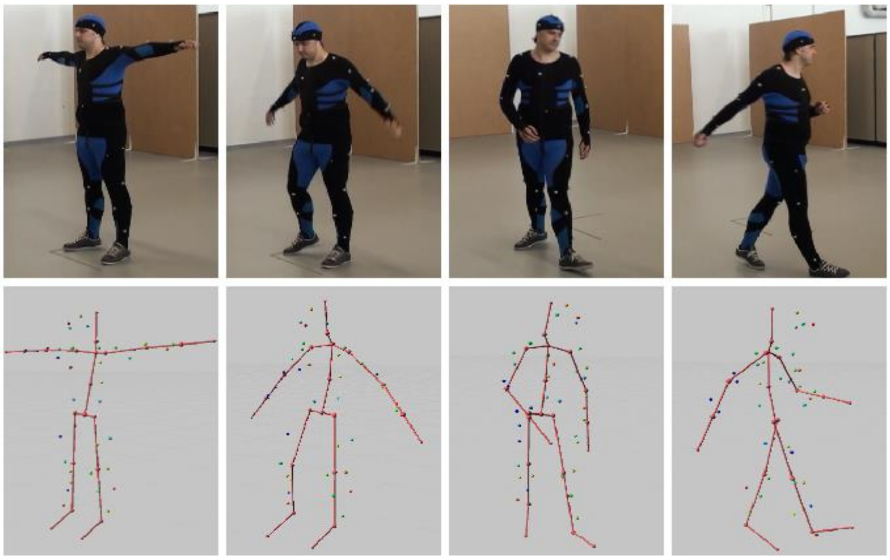
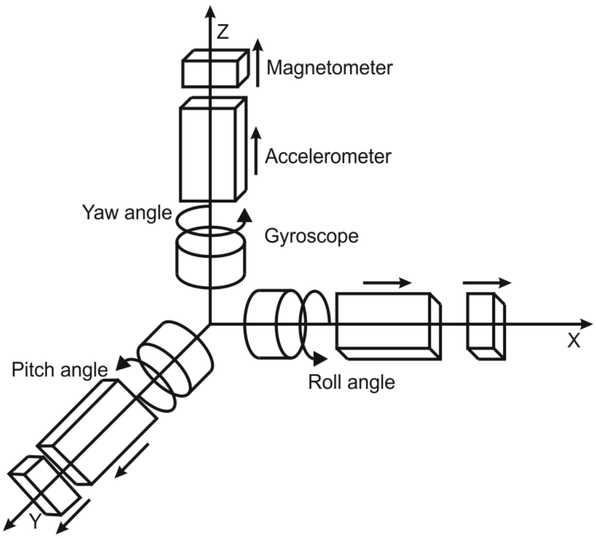


Figure from Online marker labeling for fully automatic skeleton tracking in optical motion capture

3.7.2.2 Inertial Measurement Unit (IMU)

IMUs typically consist of three main components:

1. **Accelerometers:** These measure linear acceleration in three axes (x, y, and z).
2. **Gyroscopes:** These measure angular velocity or rotational speed around three axes.
3. **Magnetometers:** These measure the Earth's magnetic field, helping to determine orientation



To calculate velocity using IMUs, the following steps are involved:

1. **Acceleration Data:** The IMU continuously measures linear acceleration in three dimensions.
2. **Integration:** The acceleration data is integrated over time to obtain velocity
3. **Error Correction:**

   - **Drift:** One major challenge with IMU-based velocity measurement is drift. Over time, the integration of acceleration can accumulate errors, leading to a deviation from the true velocity.
   - **Calibration:** Proper calibration of the IMU is crucial to minimize drift.
   - **Filtering:** Filtering techniques can help reduce noise and improve the accuracy of the velocity estimates.

Applications of IMUs:

- Consumer electronics:
- Robotics:
- Autonomous vehicles:
- Aerospace and defence
- Virtual and augmented reality

3.7.3 Acceleration Measurement

Ground Reaction Force (GRF) Measurement for Acceleration Measurement

- Ground Reaction Force (GRF) refers to the force exerted by the ground on a body in contact with it.
- This force is equal and opposite to the force exerted by the body on the ground, as per Newton's third law of motion. By measuring GRF, we can indirectly calculate acceleration.

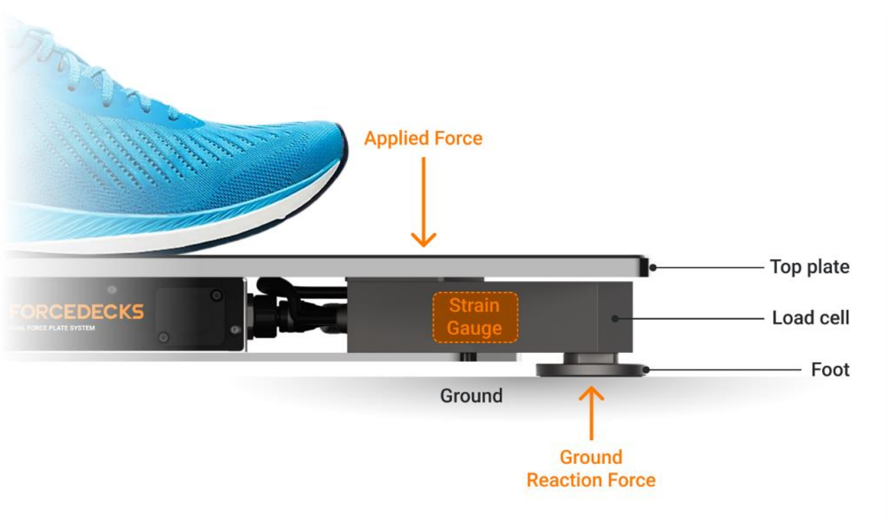
Force Plate Measurement:

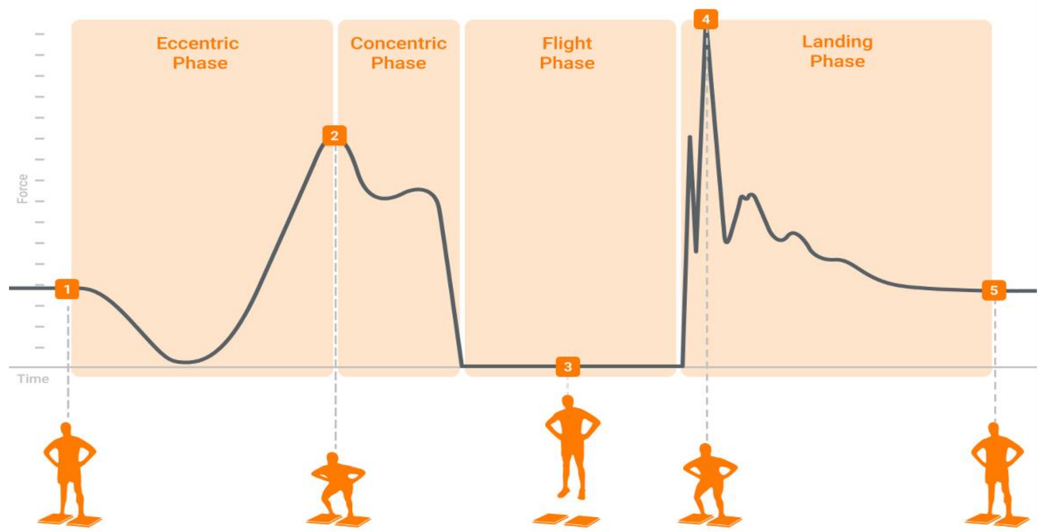
- GRF is typically measured using force plates embedded in the floor. These plates contain strain gauges that measure the deformation of the plate under load, which is directly proportional to the applied force.

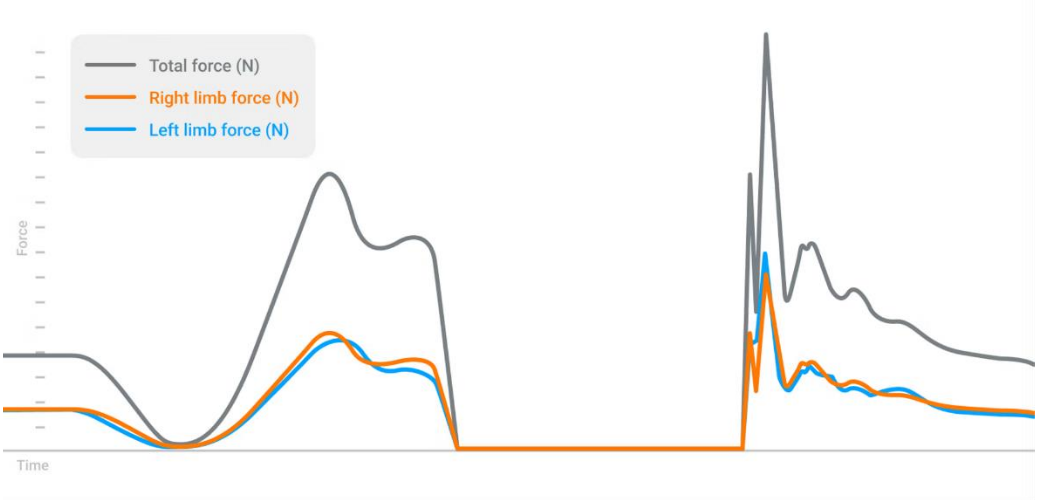
The force plate records the force in three dimensions: vertical, anterior-posterior, and mediolateral.

Calculating Acceleration:

- **Newton's Second Law:**
    - F = m * a
    - Where:
        - F = Force (GRF)
        - m = Mass of the body
        - a = Acceleration
- By rearranging the equation, we can calculate acceleration:
    - a = F / m
- The measured GRF is divided by the body's mass to obtain acceleration.





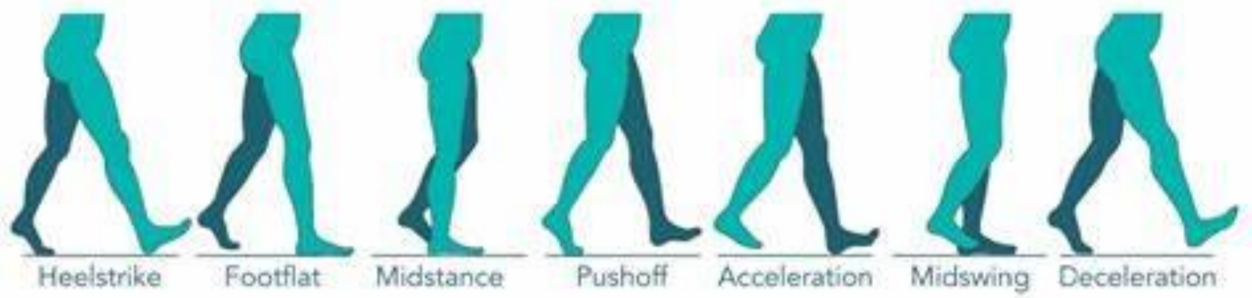


<u>**Applications of GRF and Acceleration Measurement:**</u>

- **Sports Performance Analysis:**
  - Analyzing running mechanics, jumping techniques, and power output.
  - Identifying areas for improvement in technique and training.
- **Clinical Gait Analysis:**
  - Evaluating gait patterns in individuals with gait disorders.
  - Monitoring the effects of interventions and rehabilitation programs.
- **Ergonomics and Occupational Biomechanics:**
  - Assessing the biomechanical demands of work tasks.
  - Designing ergonomic workstations and tools to reduce injury risk

3.7.4 Gait Analysis

- Gait analysis is a technique used to study the mechanics of human walking.
- It involves the evaluation of various factors such as joint angles, muscle activity, and ground reaction forces to assess normal and pathological gait patterns.
- This information is crucial for understanding the underlying causes of gait deviations and developing effective interventions.



Examples of clinical pathologies currently served by gait analysis include

- Amputation
- Cerebral palsy
- Degenerative joint disease
- Joint pain
- Joint replacement
- Poliomyelitis
- Multiple sclerosis
- Muscular dystrophy
- Myelodysplasia
- Rheumatoid arthritis
- Spinal cord injury
- Stroke
- Traumatic brain injury

3.7.4.1 Gait Cycle:

- The gait cycle is defined as the period of time from the point of initial contact (also referred to as foot contact) of the subject's foot with the ground to the next point of initial contact for that same limb.
- Dividing the gait cycle in stance and swing phases is the point in the cycle where the stance limb leaves the ground, called toe off or foot off.
- Gait variables that change over time such as the patient's joint angular displacements are normally presented as a function of the individual's gait cycle for clinical analysis.

3.7.4.2 GAIT Data for clinical analysis:

Data that are currently provided for the clinical interpretation of gait may include

- A video recording of the individual's gait (before instrumentation) for qualitative review and quality control purposes
- ***Static physical examination measures***, such as passive joint range of motion, muscle strength and tone, and the presence and degree of bony deformity
- Segment and joint angular positions associated with standing posture

- ***Stride and temporal parameters***, such as step length and walking velocity
- Segment and joint angular displacements, referred to as kinematics
- The forces and torque applied to the subject's foot by the ground, or ***ground reaction loads***
- The reactive intersegmental moments produced about the lower extremity joints by active and passive ***soft tissue forces*** as well as the associated mechanical power of the intersegmental moment, collectively referred to as kinetics
- Indications of muscle activity, that is, voltage potentials produced by contracting muscles, known as dynamic ***electromyography*** (EMG)
- The dynamic pressure distributions on the plantar surface of the foot, referred to as ***pedobarography***
- A measure of metabolic energy expenditure, for example, oxygen consumption, energy cost

Overview of technologies that are available to measure the dynamic gait

- Stride and temporal parameters,
- Motion Measurement (kinematics)
  - ✓ Electrogoniometry
  - ✓ Accelerometry
  - ✓ Video camera-Based Systems
- Ground Reaction Force Measurement
  - ✓ Force Platforms
  - ✓ Pedobarography
- Dynamic Electromyography

Stride and temporal parameters:

Stride and temporal parameters are key components in the analysis of gait, which refers to the pattern of movement of the limbs during locomotion. Here's a breakdown of these terms:

Stride Parameters

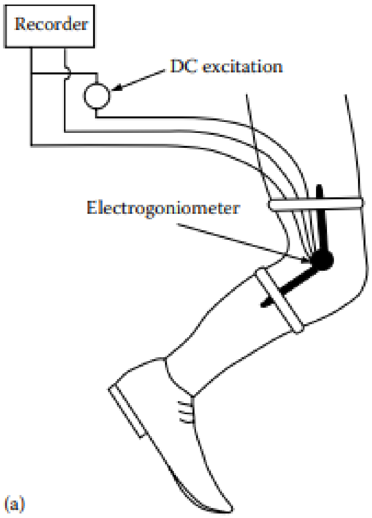
- **Stride Length:** The distance covered by one full step cycle, measured from the heel strike of one foot to the heel strike of the same foot again.

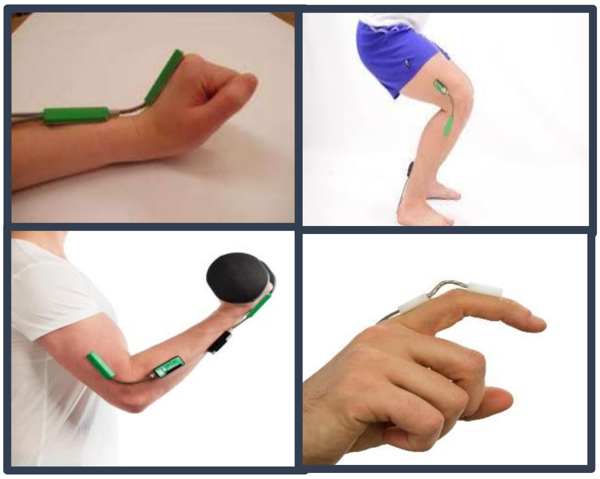
- **Step Length:** The distance covered by a single step, measured from the heel strike of one foot to the heel strike of the opposite foot.
- **Temporal Parameters**
  - **Stride Time:** The time taken to complete one full stride cycle.
  - **Step Time:** The time taken to complete one step.
  - **Cadence:** The number of steps taken per minute.
  - **Gait Speed:** The distance covered per unit of time, typically expressed in meters per second or kilometers per hour.
  - **Single Support Time:** The amount of time during a gait cycle when only one foot is in contact with the ground.
  - **Double Support Time:** The amount of time during a gait cycle when both feet are in contact with the ground.

Electrogoniometry:

An electrogoniometer is an electronic device used to measure *joint angles* and *movements*

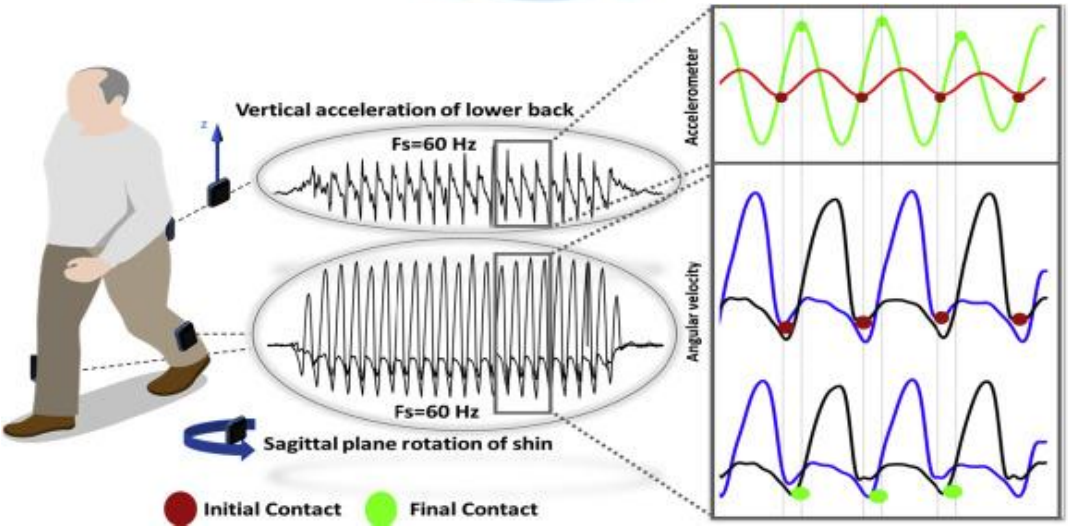
1. **Placement:** The electrogoniometer is placed over a joint, with its end blocks fixed at two points across the joint.
2. **Angle Measurement:** As the joint moves, the electrogoniometer measures the change in the angle between the two points.
3. **Data Output:** The measured angle is typically displayed on a screen or recorded for later analysis.
4. The rotational potentiometer is used to measure rotational motions of the body such as joint motion.
5. The goniometer is an instrument which is attached to the body and measures angular displacements of a joint.
6. A simple goniometer consists of a rotational potentiometer as shown in Figure.
7. However, an actual joint motion is not a simple rotation around one fixed axis, but has a higher degree of freedom. For precise measurement of a joint motion, the goniometer used has three rotational potentiometers so that it measures rotations in sagittal, coronal, and transverse planes separately.





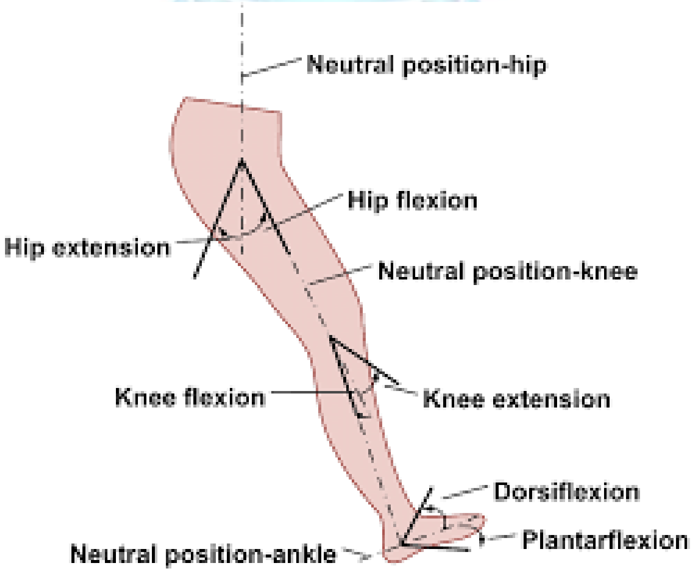
Accelerometer:

- Multiaxis accelerometers can be employed to measure both linear and angular accelerations (if multiple transducers are properly configured).
- Velocity and position data may then be derived through numerical integration although care must be taken with respect to the selection of initial conditions and the handling of gravitational effects.



- Electrodes placed on the skin's surface and fine wires inserted into muscle are used to measure the voltage potentials produced by contracting muscles.
- The activity of the lower limb musculature is evaluated in this way with respect to the timing and the intensity of the contraction.
- Data collection variables that affect the quality of the EMG signal include the placement and distance between recording electrodes, skin surface conditions, distance between electrode and target muscle, signal amplification and filtering, and the rate of data acquisition.
- The phasic characteristics of the muscle activity may be estimated from the raw EMG signal.
- The EMG data may also be presented as a rectified and integrated waveform. To evaluate the intensity of the contraction, the dynamic EMG amplitudes are typically normalized by a reference value, for example, the EMG amplitude during a maximum voluntary contraction.
- This latter requirement is difficult to achieve consistently for patients who have limited isolated control of individual muscles, such as children with cerebral palsy (CP).

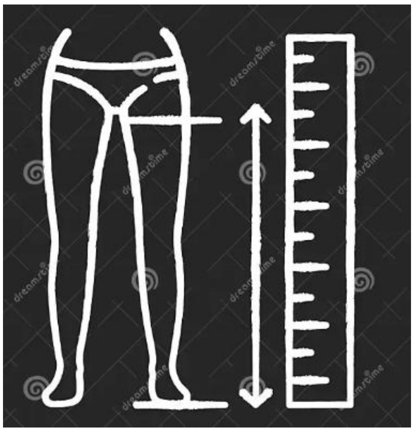
Measurement of Limb Position:



There are several methods for measuring limb position, each with its own advantages and disadvantages. Here are some of the most common methods:

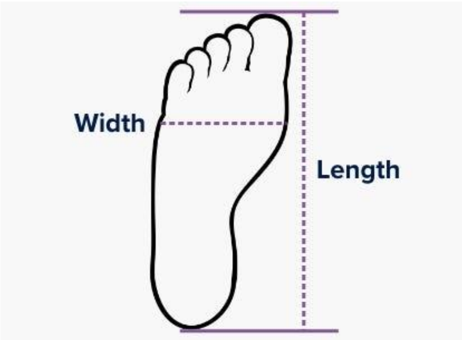
- **Manual measurement:** Using a tape measure or goniometer to directly measure joint angles and limb lengths. This method is simple and inexpensive, but it is also prone to error and requires specialized training.
- **Electromyography (EMG):** Measuring the electrical activity of muscles to infer limb position. This method is non-invasive and can provide real-time information about limb movement, but it is sensitive to noise and requires specialized equipment.
- **Inertial measurement units (IMUs):** Using accelerometers and gyroscopes to track limb movement. This method is non-invasive and can provide accurate information about limb position and orientation, but it is sensitive to environmental disturbances and requires calibration.
- **Motion capture systems:** Using cameras and markers to track limb movement in three dimensions. This method is highly accurate and can provide detailed information about limb position and orientation, but it is expensive and requires specialized equipment and software.
- **Ultrasound:** Using sound waves to image the internal structures of the body, including muscles and bones. This method is non-invasive and can provide detailed information about limb position and orientation, but it is limited by the depth of tissue that can be imaged.
- The best method for measuring limb position will depend on the specific application and the desired level of accuracy. It is important to choose a method that is appropriate for the task at hand and to ensure that the measurements are accurate and reliable.

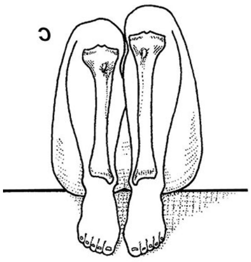
Measurement of Leg Length

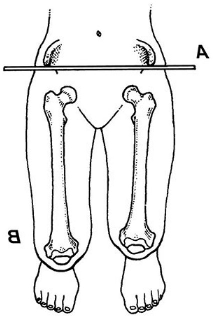


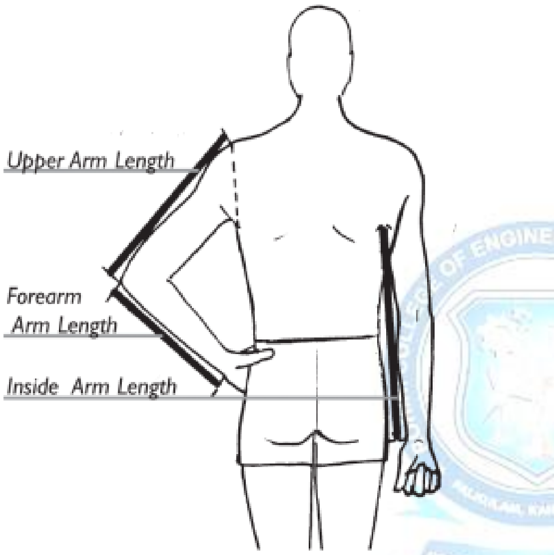
Measurement of Foot Length

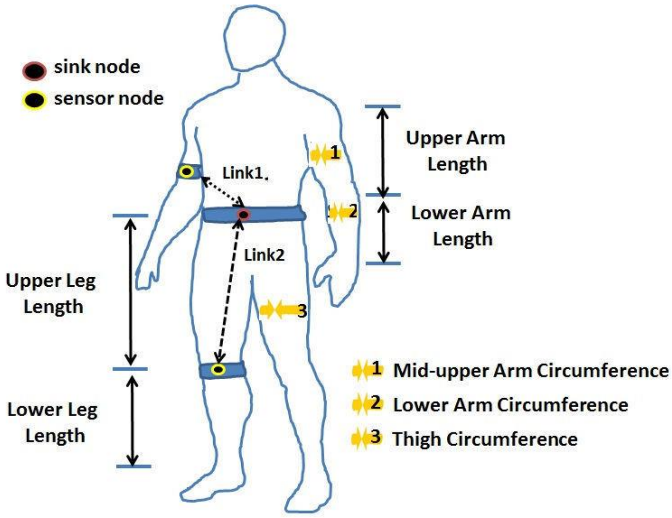
Measurement of Foot Width







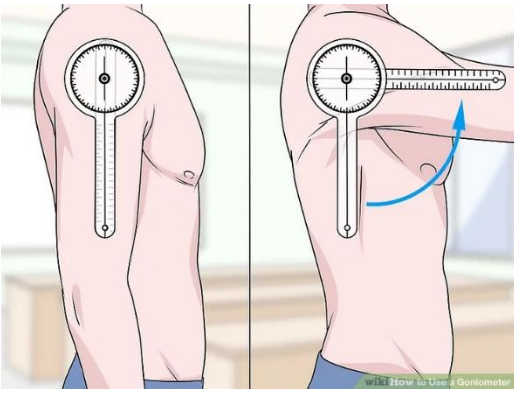




Goniometer:

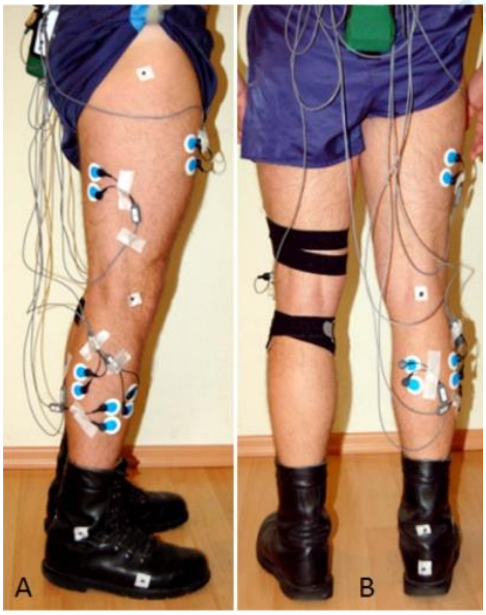
Use the goniometer to find the range of motion for a shoulder joint.

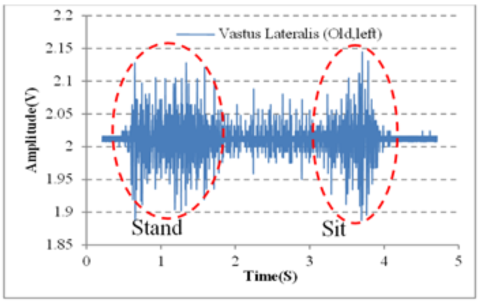
To measure the lateral rotation of the shoulder, start by holding the arm straight down against the body. Move the arm slowly upwards, stretching as far as possible. Measure the angle using the goniometer. To measure the backwards flexion of the shoulder, start with the arm down by the body and move it backwards before measuring



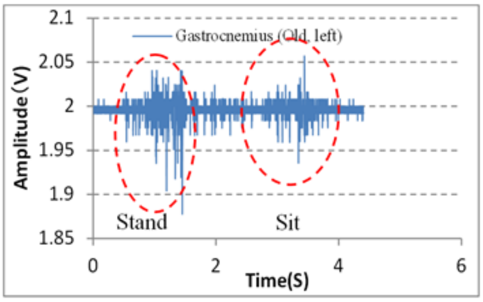
- ❑ **Position the patient:** Ensure the patient is comfortable and the joint to be measured is relaxed and free of obstructions.
- ❑ **Align the goniometer:** Place the axis of the goniometer over the axis of the joint being measured.
- ❑ **Position the arms:** Align one arm parallel to the stationary body segment (proximal segment) and the other arm parallel to the moving body segment (distal segment).
- ❑ **Read the measurement:** Read the angle indicated on the protractor scale where the two arms intersect.

<u>Electromyography</u> (EMG):





(a)



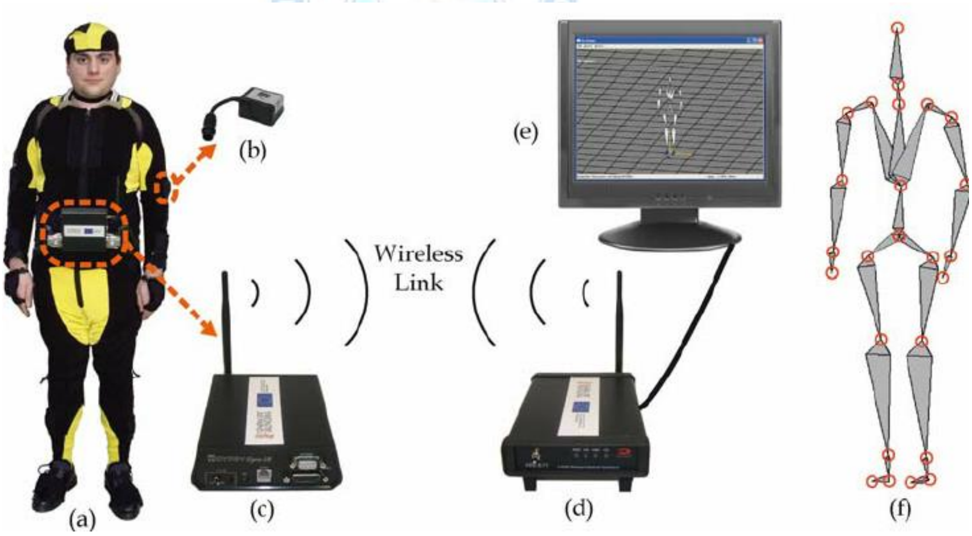
(b)

Electromyography (EMG) is primarily used to measure electrical activity produced by skeletal muscles, typically in response to neural stimulation. By analyzing EMG signals, it is possible to infer information about limb movements, muscle activation patterns, and sometimes even approximate joint angles or limb positions.

Inertial measurement units (IMUs):

- **Accelerometer:** Measures linear acceleration in three axes (x, y, z).
- **Gyroscope:** Measures angular velocity (rate of rotation) in three axes.
- **Magnetometer:** Measures the Earth's magnetic field, helping to determine orientation.
- By integrating the acceleration and angular velocity data over time, the IMU can calculate the change in position and orientation of the limb segment.
- This information can be used to estimate the joint angles and the overall 3D position of the limb in space.

Motion capture systems:



Marker-Based Systems:

Markerless Systems: Advanced computer vision algorithms to track the body's contours and movements without the need for markers

Inertial Motion Capture Systems (IMUs): Including accelerometers, gyroscopes, and magnetometers

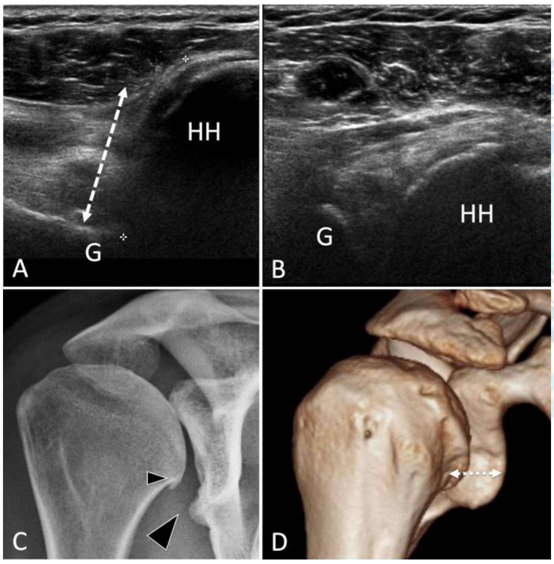
Ultrasound:

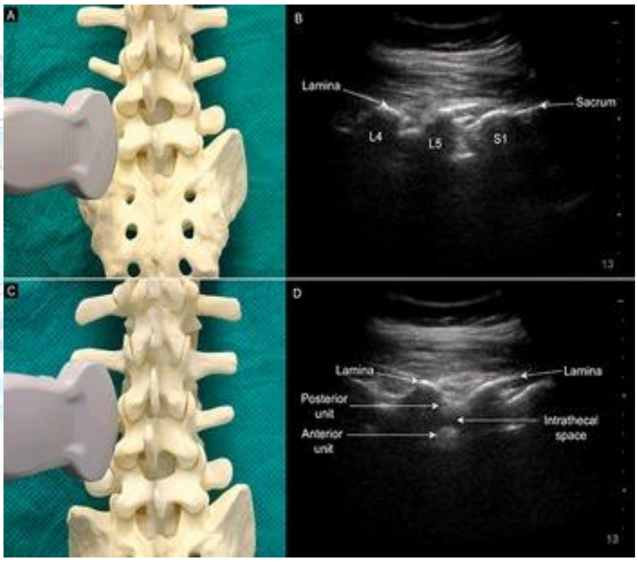
Landmark Tracking:

- By identifying specific anatomical landmarks (like bone protrusions or muscle insertions) using ultrasound, the relative position of these landmarks can be tracked.
- Changes in their positions can indicate limb movement.

Tissue Deformation Analysis:

- Ultrasound can visualize the deformation of soft tissues during movement.
- By analyzing the extent and direction of tissue deformation, it's possible to estimate joint angles and limb position.





- Ultrasound imaging can be used for limb position measurement by visualizing muscles, tendons, and bones in real-time. Unlike electromyography (EMG), which measures muscle activation, ultrasound.
- Ultrasound for limb position measurement offers rich, high-resolution information on muscle and tendon movements, making it a valuable tool in clinical and biomechanical research settings. However, due to its limitations, it’s often used in combination with other methods for comprehensive limb position tracking.

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