Biomechanical Principles of Orthotics

By:

Dr. Ahmed Abd El-Moneim

Lecturer of Physical Therapy

Beni-Suef University

Coordinator of Prosthetics & Orthotics Technology Program, BSTU

Ph.D, Cairo University

Diploma of Osteopathic Medicine, IAO (Belgium)

Diploma of Therapeutic Nutrition, NNI

Introduction

- A relatively comprehensive understanding of mechanical principles is necessary for orthotists and bioengineers who design orthoses.
- Rehabilitation specialists need a basic knowledge of mechanics to interpret proper fit and function of an orthosis.

Biomechanics of Orthosis

- There are four different ways in which an orthosis may modify the system of external forces and moments acting across a joint.

1) Control of rotational moments across a joint.
2) Control of translational forces around a joint.
3) Control of axial forces around a joint.
4) Control of line of action of ground reaction force. This involves modifying the point of application and line of action of the ground reaction force during static or dynamic weight bearing.

Biomechanics of Orthosis

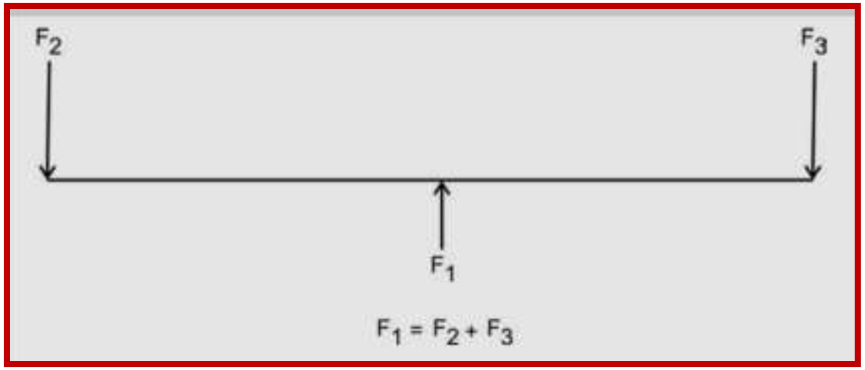
- The first three are termed as **"<u>Direct</u>"** in that the orthosis actually surrounds the joint being influenced.
- The fourth may be termed **"<u>Indirect</u>"** as the orthosis modifies the external force system acting beyond its physical boundaries.

Principle of Jordan

- The basic mechanical principle of orthotic correction is the **"<u>Three point system of Jordan</u>".**
- This system applies corrective or assistive forces, which are implemented at the surface of the orthosis through the skin and are transmitted to the underlying soft tissues and bones.
- To remain stable, the body has to have one point of pressure opposed by two equal points of counter pressure in such a way that **<u>F1 = F2 + F3</u>.**

Principle of Jordan

- **<u>Principle of Jordan</u>:**
- To remain stable, the body has to have one point of pressure opposed by two equal points of counterpressure in such a way that **<u>F1 = F2 + F3</u>.**



Principle of Jordan

- The corrective force is directed toward the angular or deformed area to be corrected, and other two counter forces are applied distal and proximal to the corrective force.
- The greater the distance between the force and the counter forces, the less the counter force required.

1) Force

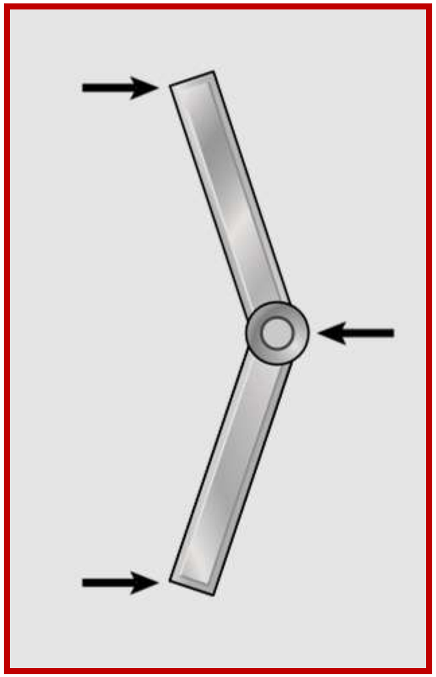
- Orthoses are '**force systems**' that are applied to the body to control motion of various skeletal segments.
- A **force** has both direction and magnitude, and the principles guiding their integration into an orthosis determine, in part, their efficiency and effectiveness.

1) Force

- Usually an orthosis applies several forces that interact and resolve to create the desired orthotic control. This system, known as a **force couple**, contains two equal forces, in opposite directions.
- A **three-point force couple** is one of the most fundamental mechanical principles incorporated into an orthosis.

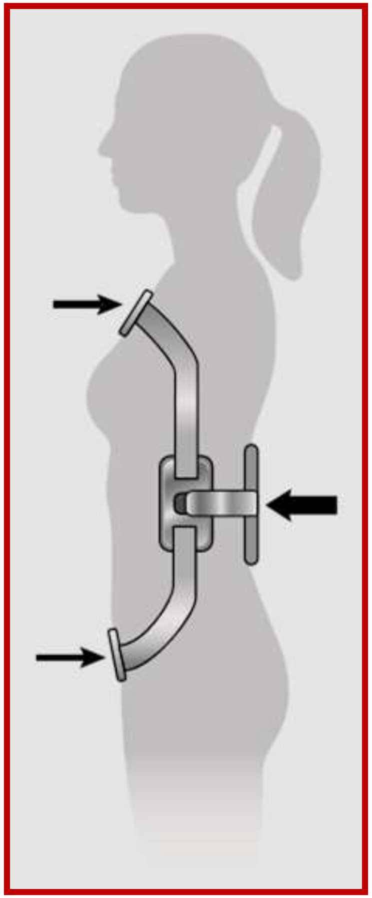
1) Force

- Three-point force couple. A force system that applies two equal forces in opposite directions.
- The single arrow on the right represents the corrective force and the two opposing arrows represent the counter forces.



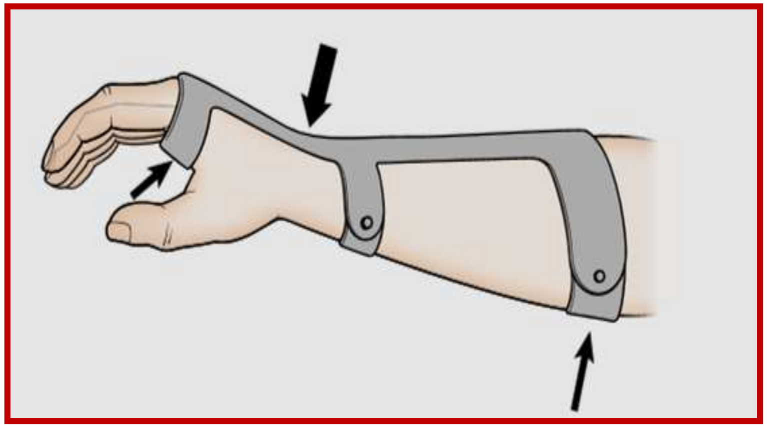
1) Force

- **Example:** TLSO → A three-point force couple to resist trunk flexion.



1) Force

- **<u>Example</u>:** WHO → A three-point force couple to control for wrist flexion.

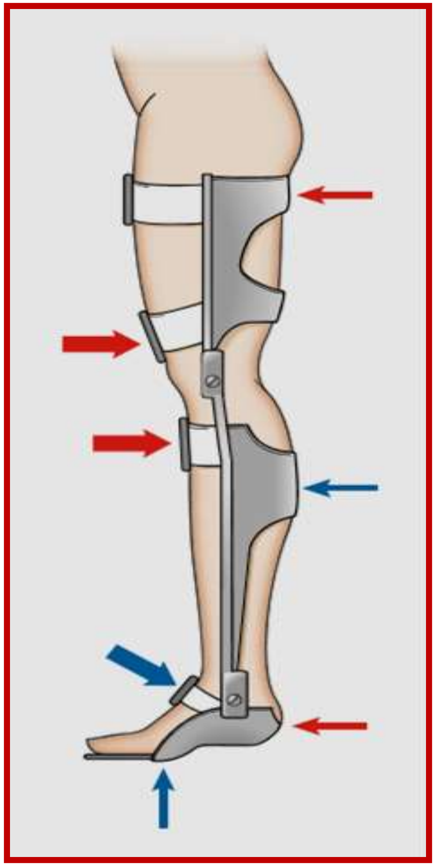


1) Force

- Some orthoses have multiple force couples in play.
- **For example:** in a KAFO, in which both the knee and ankle joints may need to be controlled, multiple force couples are at work in which some of the force application regions may be shared.

1) Force

- Multiple-point force couples in a KAFO.
- The blue arrows show control of the ankle to resist plantar flexion and the red arrows show the force couple for resisting knee extension.



2) Gravity

- Gravity pulls the body toward the ground and the opposing reaction force from the body-ground interaction is known as the ground reaction force (GRF).
- This external force is an important factor because GRFs significantly alter the interface pressures between the orthosis and body segment(s).

2) Gravity

- **<u>Example</u>:** an AFO designed to hold the ankle in the neutral position (90°) in a non-weight bearing situation will possess lower interface pressures than when an individual stands or walks (the stance phase of gait) due to the external GRFs.
- With a good understanding of the mechanics of gait, GRF can be capitalized to control joint motions. By blocking motion of a joint, the GRF can induce a joint moment at the nearest proximal joint.

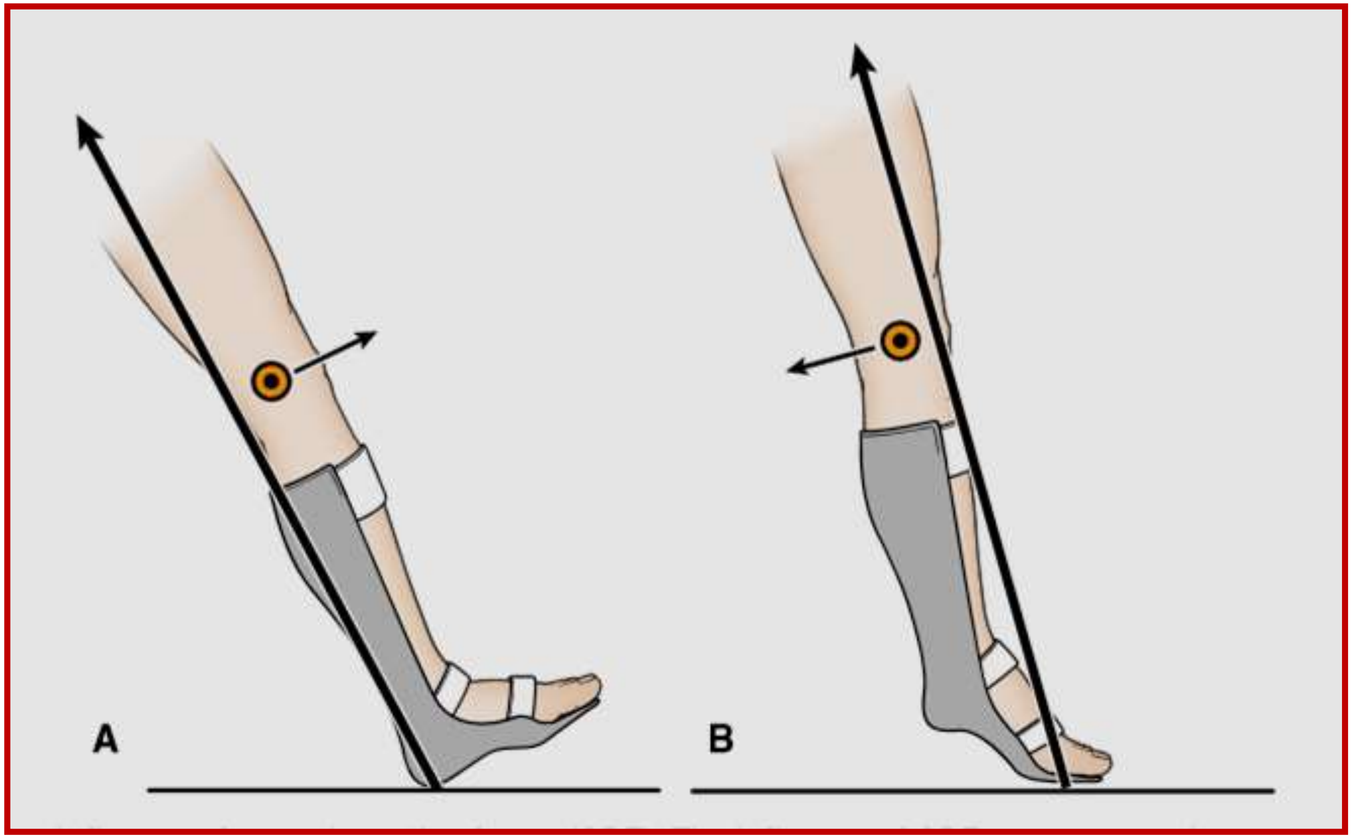
2) Gravity

- **Example:** A solid AFO may control knee motion during a portion of the stance phase of walking.
  - If the AFO holds the patient’s ankle and foot complex in plantar flexion, then the GRF may induce a knee extension moment during the early portion of stance phase.
  - If the AFO holds the patient’s ankle and foot complex in dorsiflexion, then a knee flexion moment during the early portion of stance phase may be induced.

2) Gravity

- Influence of GRFs can occur only during the stance phase of gait and if ankle joint motion is blocked.
  - When the foot/ankle is held in dorsiflexion, the GRF is posterior to the knee joint axis and a knee flexion moment is present.
  - When the foot/ankle is held in plantarflexion, the GRF is anterior to the knee joint axis, and a knee extension moment is present.

2) Gravity



2) Gravity

- Ground reaction force control can only occur during the stance phase of walking unlike three point force couple systems, which provide control during both stance and swing phase.

3) Moment Arm

- Management of forces in an orthosis may be complicated due to the many interrelated components affecting how the forces are applied to the body. The criteria for orthotic design are founded on basic mechanical principles.
- A moment arm is the distance from the respective joint axis to the point where the interface force of the orthosis is applied.

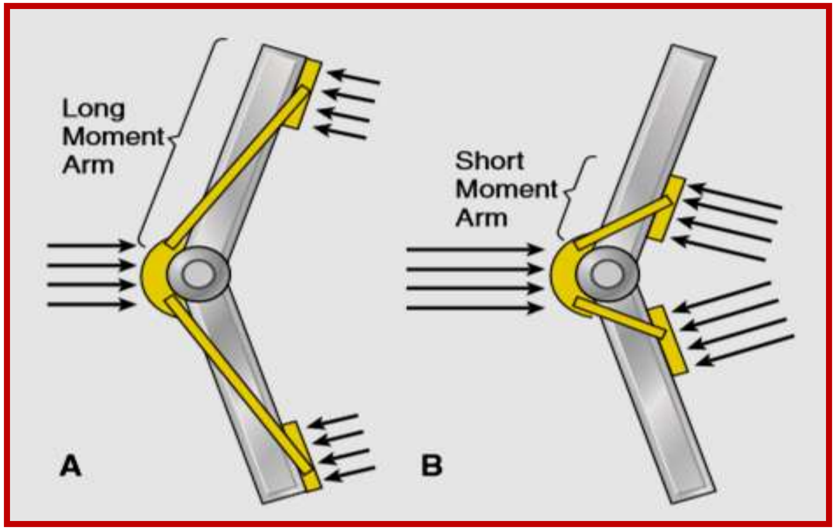
3) Moment Arm

- Orthoses with short moment arms produce higher interface pressures than orthoses with long moment arms.
- **Example:** The length of an orthosis often correlates with the length of its moment arm, due to its corresponding influence on the interface pressure applied by the orthosis.

3) Moment Arm

- Length criteria for orthoses (long vs. short):-

- An orthosis with a short moment arm will possess higher orthotic interface pressures compared to a device with a longer moment arm.



3) Moment Arm

- Maximizing the length of an orthosis (inherently its moment arm) is generally preferred over shorter orthotic devices.
- This is an important factor for the capacity of orthoses to provide the necessary forces to control movement while also insuring the wearer's comfort and tolerance.


Thank you