Using Biomechanical Principles in the Management of Complex Postural Deviations in Sitting

ISS 2016 / Part 1 - Basic Principles

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Goals

- Be able to determine intervention strategy based on biomechanical principles when working with individuals with complex postural problems
- Be able to predict patterns of posture and movement
- Understanding cause and effect – address the cause, not just the symptoms
- Better outcomes for your clients
- More efficiency for you – proactive vs. reactive.

Using Biomechanical Principles in the Management of Complex Postural Deviations in Sitting

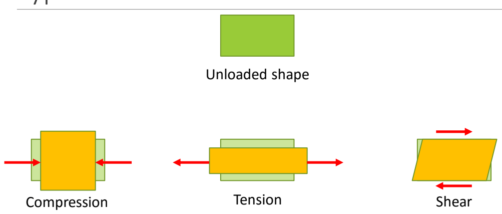
I. **BASIC PRINCIPLES**
  - **REVIEW OF BIOMECHANICS PRINCIPLES**
  - **GENERAL SEATING APPLICATION**

II. **MANAGING COMPLEX POSTURAL DEVIATIONS USING A BIOMECHANICAL APPROACH**

Basic Principles

- Forces
- Motion
- Moment Arms
- Equilibrium
- Stability and Center of Mass
- Balance

Types of Forces



Types of Forces

Forces can be

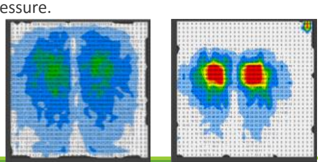
- **Internal** – bone, ligament, tendon, muscle, intra-abdominal pressure, etc.
- **External** – support surfaces, straps & harnesses, etc.
- **Gravity**

Unlike the internal and external forces, **gravity is constant in magnitude and direction**

Body weight is the effect of the force of gravity acting on the body's mass.

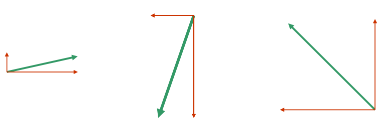
Pressure vs. Force

- In many cases, force isn't the critical variable
- Force divided by the area over which it is applied is pressure (or stress)
- In the case of bodyweight, we can't do much about the force, but we can modify the pressure.



The resolution of forces

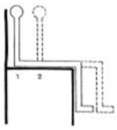
- In force diagrams, a force is represented by an arrow (vector)
- Any force can be "resolved" or broken down into two components (e.g. horizontal and vertical, or normal and shear)

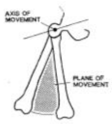


Effect of a Force

A force can result in a

- Deformation
- Translation
- Rotation.





Translational Movement = All parts of the body move exactly the same distance, in the same direction, and in the same time (Nwaobi, 1984)

Rotational Movement = when a body moves along a circular path about some point in space so that all parts of the body travel through the same angle (Nwaobi, 1984)

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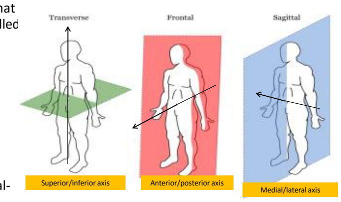
Joint Motion of individual body segments are *Rotational Movements*

Motion of the limb occurs around an ***axis*** that is perpendicular to the plane. This axis is called the ***axis of rotation.***

Transverse plane motions occur about the superior-inferior axis

Frontal plane motions occur about the anterior-posterior axis

Sagittal plane motions occur about a medial-lateral axis



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Body Planes and Axes of Rotation

Activity/Demo

Degrees of Freedom

- Our joints have multiple degrees of freedom (DOF)
- The DOF may be coupled (they aren't independent, palmar flexion results in radial deviation)
- There may be coupling of DOF from other joints (hip flexion pulls on the hamstrings which may cause knee flexion).

Range of Motion and Limits

Joints have a range of motion (ROM) for each degree of freedom

The ROM may be limited

- **Passively (internal)** - bony impingement, ligament/capsule tension, muscle/tendon passive force, soft tissue impingement
- **Passively (external)** – braces/orthoses, seating systems, etc.
- **Actively (internal)** – muscle contraction.

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Moment Arms (think of a teeter-totter)

- The further the load acts from a joint, the greater the effect on that limb segment
- The further the load acts from a desired location on a body part, the greater the effect.
- Moment arm = force * distance.

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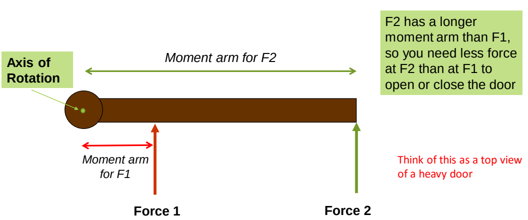
Moment Arms



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Moment Arms

All of the following result in a moment of 10 foot-pounds

- 1 lb at a distance of 10 feet
- 5 lbs at a distance of 2 feet
- 10 lbs at a distance of 1 foot
- 20 lbs at a distance of ½ of a foot
- 100 lbs at a distance of 1/10 of a foot

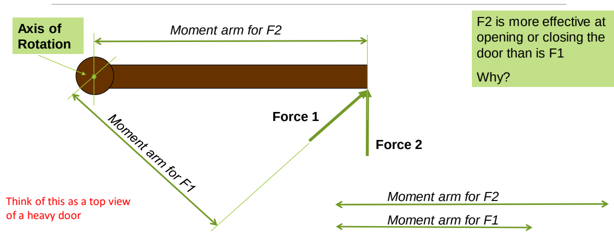
So, if you need to resist hip abduction and you need 10 foot-pounds to do so, putting the blocking pad 1 foot from the hip requires ½ the force compared to if it was 6" from the hip

Less force means greater comfort for your client and better durability of your hardware.

Moment Arms

To get the most out of the force you apply, you want it to be perpendicular to the direction of movement that you are trying to cause or restrain.

Moment Arms



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Equilibrium

- If an object isn't changing speed, it is said to be in a state of equilibrium
- We tend to simplify this to "bodies at rest"
- Equilibrium tells us that all of the forces are balancing each other

Example:

- Hold your arm out to side. To do so your middle deltoid is generating a force that is creating a moment that is balancing the moment produced by gravity. Your arm is in equilibrium.
- Lower your arm to rest on an armrest or your thigh. The support surface creates a force that is equal and opposite to gravity. Your arm is in equilibrium.

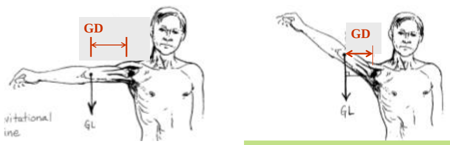
Activity

Hold one arm out to side and other arm angled up above horizontal

Which arm gets tired faster

Why?

Rotational Equilibrium and the Gravitational Moment



GL=gravitational line

GD=gravity moment arm (distance)

The gravitational moment about the shoulder joint is LESS in this position, therefore you don't have to generate as much force via your deltoid muscle to hold your arm up

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For every action (force), there is an equal and opposite reaction (force)

(Newton's Third Law of Motion)

Given a state of static equilibrium, every force exerted by the person's body while sitting in a seating system is balanced by an opposite force exerted by the support surface on the person.

Gravity pulls down on the body. That pull is resisted by the seating surfaces. The two forces are equal and opposite.

A lateral knee support used to block active abduction movement experiences a force equal and opposite to that produced by the leg as it abducts.

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Stability

- We tend to be seeking stability in most of what we do
- **Stability** = "the ability of an object…to maintain equilibrium or to resume its original position after displacement" (American Heritage Dictionary)
- There are several ways to view stability

Stability *Positive-Neutral-Negative*

- **Positive** – ball in a bowl, the natural tendency is for the ball to return to the original position
- **Neutral** – ball on a table, the natural tendency is for the ball to stop where it is released
- **Negative** – ball on a dome, the natural tendency is for the ball to move away from its initial position

Stability *Static vs. Dynamic*

- **Static** – balance on a bike while standing still
- **Dynamic** – balance on a bike while rolling.

Postural Stability

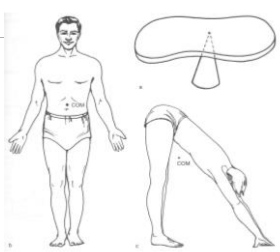
- **Postural stability** describes the ability of one body segment to remain steady while an adjacent segment moves (Ward, 1994)
- In seating, when we "stabilize" a body segment, we are usually attempting to limit or prevent movement of that segment, for the purpose of improving overall postural stability or to allow improved motor control at an adjacent or more distal body segment.

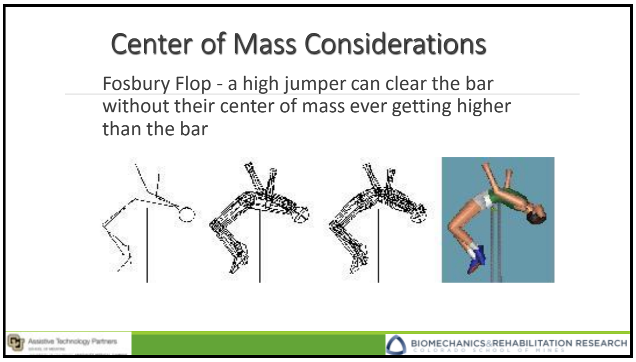
Center of Mass (COM), or Center of Gravity (CG)

- The point where all of the mass of an object (body, body segment) could be considered to be concentrated
- We can find the COM for the upper arm, the forearm, the hand and fingers, or combinations
- The location of the COM can vary with joint position or posture
- For a solid object, the COM is the point where the object would balance
- The COM does not have to be within the boundaries of the body.

Center of Mass

The center of mass of the body may move as the body's configuration changes




Center of Mass Considerations
Fosbury Flop - a high jumper can clear the bar without their center of mass ever getting higher than the bar
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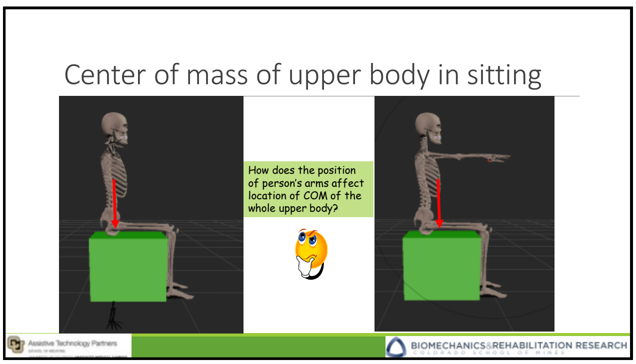
Center of mass of upper body in sitting
How does the position of person's arms affect location of COM of the whole upper body?
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Center of Mass/Center of Gravity
What's the big deal?

- The location of the COM depends on how the mass is distributed, so it is affected by ***body posture***
- Why is the location of a body segment's COM/CG important to us?

Because the **point of application** of the gravitational force on a body is at that body's *COM/CG*, and that affects the amount of gravitational pull acting on that body area

……so you can change how gravity is pulling on the body by changing the body's posture!

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Center of Mass and Base of Support

- A body's center of mass must be over its base of support in order to be balanced.
- A wider base of support provides more stability because the center of mass can move and still be within the base of support.
- Similarly, the lower a body's center of mass, the more stable the body is.

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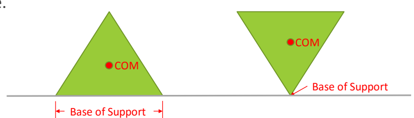
Base of Support

The footprint over which an object is stable

- Stand or sit with legs together and sway side to side, you will quickly lose your balance
- Stand or sit with legs apart and sway, you'll be much more stable.



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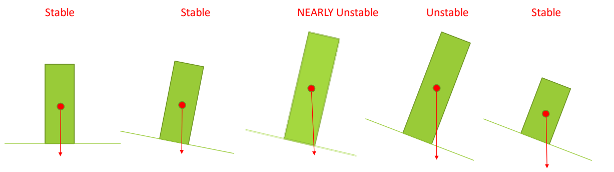
COM vs. Base of Support

As long as the COM is above the base of support, the object will be stable.



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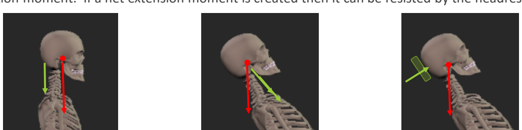
Balance

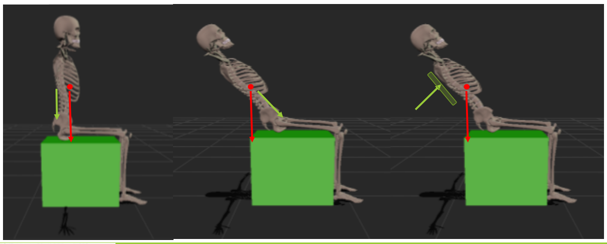
Our bodies are not symmetric (A-P), so gravity tends to lead to movements that must be overcome

When we are sitting in an upright posture, the COM of our head is anterior to the cervical spinal column. As a result, gravity produces a spinal flexion moment. To remain upright we need to contract the cervical spine extensors to create an equal extensor moment. This gets tiring.

Reclining changes the line of action of the gravitational force thereby reducing or eliminating the flexion moment. If a net extension moment is created then it can be resisted by the headrest.



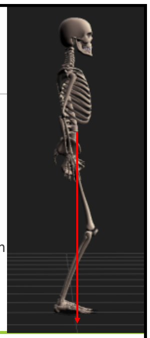
Interaction of Gravity, COM, Base of Support



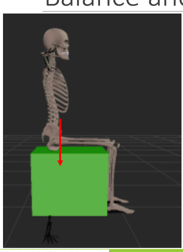
COM Relative to Joint Axis

The human body can gain stability from internal or external structures

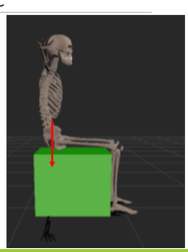
- Internal can be passive (bones, ligaments, capsules, etc.) or active (muscles)
- With the knees fully extended, the line of action of the COM is anterior to the knee axis, resulting in an extension moment. This extension is restricted by ligaments and the joint capsule.
- With the knees flexed even slightly, the line of action of the COM is posterior to the knee axis, resulting in a flexion moment. This flexion can only be restricted by muscular contraction.



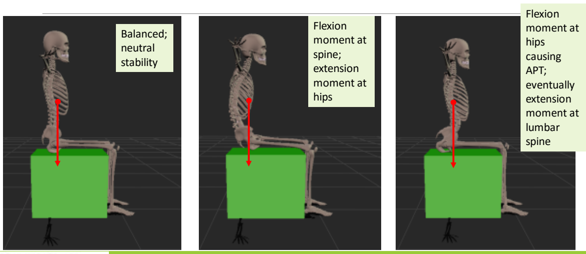
Balance and Postural Collapse



> "…in order to minimize muscular contraction and facilitate relaxation in the sitting position, the line of gravity needs to remain close to the joints which provide a biomechanically stable posture"
>
> (Nwaobi, 1984)



How Do We Gain Stability?



How Do We Gain Stability?

1. **Muscle activation**
   - Will be fatiguing, can cause pain, and stability through muscles may not be an option (weakness, paralysis)
2. **Ligaments**
   - Stability through passive soft tissues (hanging on ligaments or other internal structures at end range)
   - Can cause pain; lead to deformity
3. **External support**
   - back supports, lateral supports, etc

Excessive APT and lumbar extension

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Seating Application

- **Biomechanics principles come into play in seating in these primary areas**:
  - ✓ Understanding postural collapse and balance
  - ✓ Analyzing and predicting patterns of posture and movement
  - ✓ Understanding how joint restrictions affect the above
  - ✓ Blocking movement as an intervention –knowing where to place support surfaces
  - ✓ Dynamic Seating Systems and Restorative Forces
- **Blocking Movement or Providing a Restoring Force – Why?**

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Why Block Movement?

- General seating strategy is to achieve balance between stability and mobility
- Allow and facilitate active functional movement, while providing proximal stability to support and optimize that movement
- May require blocking undesired movement, or stabilizing certain segments, in order to achieve more functional movement elsewhere
- Preventing postural deviations which interfere with health, safety, comfort or function may also require blocking some movements – either active or passive movement (postural collapse)

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General Application of Biomechanics Principles

- Balance vs. Postural Collapse
- Blocking Movement: *Equal and Opposite Forces*
- Blocking Movement: *Mechanical Advantage*
- Blocking Movement: *3-point Control*

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Balance vs. Postural Collapse

"…in order to minimize muscular contraction and facilitate relaxation in the sitting position, the line of gravity needs to remain close to the joints which provide a biomechanically stable posture" (Nwaobi, 1984)

- Analyze the effects of gravity on the person's posture as well as movement.
- Use tilt, seating angles and external support surfaces NOT ONLY to change a person's orientation in space, but also to change the body's posture, so as to achieve maximum balance with minimum effort by the individual.

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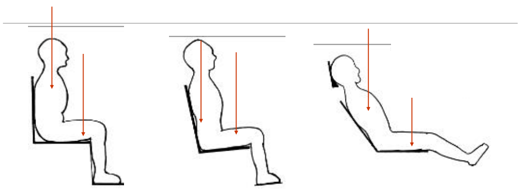
Changing orientation in space affects posture, movement and weight distribution



In seating, you can change the effect of gravity by altering the body's orientation in relation to it. The more perpendicular a body segment is to the downward line of gravity, the greater percentage of the weight above it will bear

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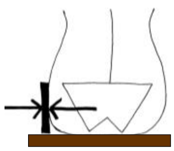
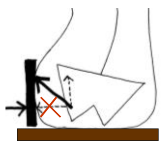
Blocking Movement:
Equal and Opposite Forces

In order to most effectively block a movement, the seating support surface, or pad, should be **perpendicular to the direction of movement** - the opposing forces are then in opposite directions.

Blocking Movement:
Equal and Opposite Forces



Pad is perpendicular to direction of movement, so movement is blocked.



Pad is not perpendicular to direction of movement, therefore only the horizontal component is blocked, leaving the vertical component unopposed.

Blocking Movement:
Mechanical Advantage

- Apply the concept of moment arms to get the most control of rotational movements with the least pressure at pad
- The farther the pad is placed away from the center of rotation, the smaller the counterforce required to hold the limb, which means **less pressure** will be felt at the pad.

Example:

- Blocking hip adduction pattern with medial knee support
- The more distal the support (farther away from hip joint which is the center of rotation), the less pressure will be felt at the pad

Blocking Movement:
3 Point Control

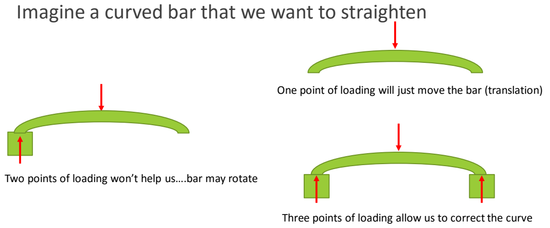
The body will move where it is mobile

- **Importance of mat exam**

- Blocking a movement may result in a different movement due to multiple degrees of freedom within that joint
- Also, blocking one body segment may result in movement of adjacent segment
- Example: Strong elbow flexion pattern
  - If you block distally at wrist, what might happen?
- This leads to the concept of **3 Point Control**

3 Points of Control

Imagine a curved bar that we want to straighten



3 Points of Control

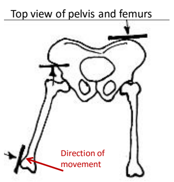
- To stabilize or prevent movement at a joint, both of the body segments articulating at the joint may need to be controlled.
- This often requires three support surfaces to be applied to the body:
  - Two pads immobilize the segments on one side, and the other pad resists movement of the center of rotation (the joint) in the opposite direction.

Activity

Client has abnormal movement pattern of hip abduction due to spasticity. You want to block this movement.

Where are the 3 points of control needed?

3 Points of Control: *Blocking active hip abduction*



Active strong abduction movement

Place lateral knee pad distally, perpendicular to direction of movement

If hip abduction force is strong enough to overcome friction on seat, *other segment will move*

Which direction will pelvis move?

To totally immobilize, 3 points of control are needed.

Questions/Comments/Discussion

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