Biomechanics

Third Stage/ Biomaterials Engineering and prosthesis Branch

Presented By

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Lecture Five

Human Movement analysis Determined Center of Mass (COM) and Stability

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- **Equilibrium**: is a state of balance in which all forces are equal
- **Stability**: is the ability of a body to resist motion and remain at rest.

Or : the ability of a body to force applied and return to its original position without damage (remain balanced).

- **Balance**: is the ability to control equilibrium during changing body's position.

- any body move reach to balance state when has center of mass (COM) and Stability.

COM + Stability ⟹ **Balance**

Center of Mass (COM)

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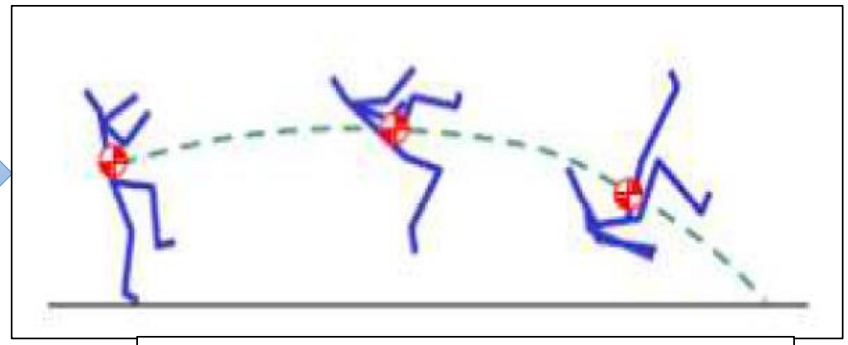
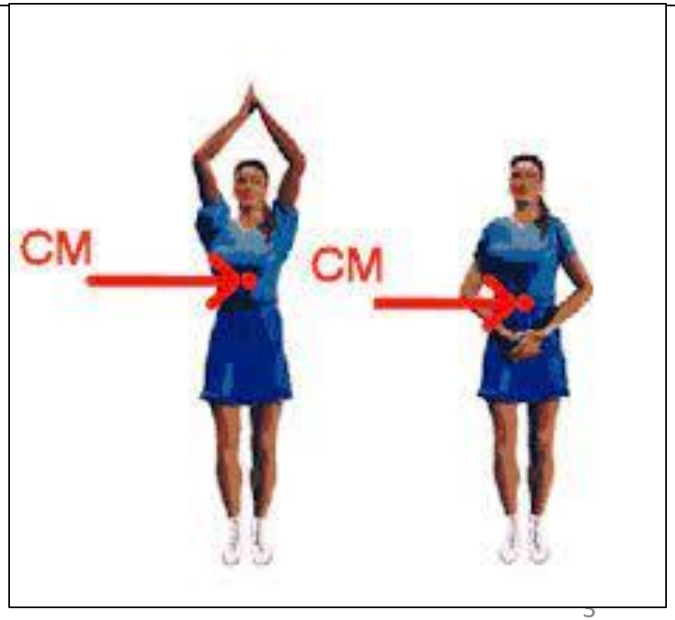
- The center of mass of a body or a system of bodies is the point that moves as though all of the mass were concentrated there and all external forces were applied there. the center of mass is referred to as the center of gravity (CoG), so can define the **center of mass** is a point at which a body is balanced in all direction.





- the center of mass is **important** as it shows where weight acts from.

Center of Mass (COM)

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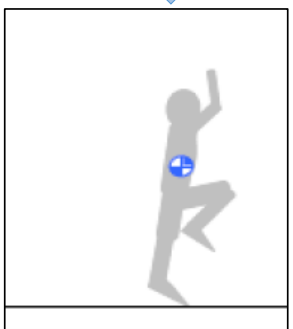
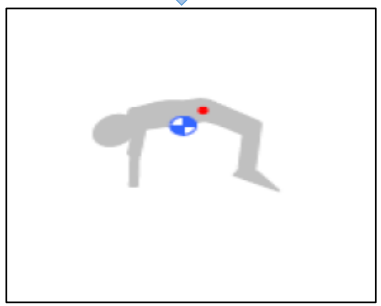
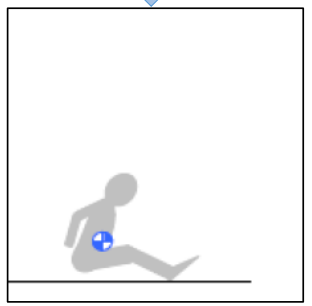
Influences of Body Position

- the center of mass changes as the high jump is performed:
- Increase take-off height of COM (raise arms)
- Increase height of individual body parts during flight (lower other parts)
- Decrease landing height (lift legs)

according to above the location of the COF is important because mechanically a body behaves as if its mass were concentrated at the COF and its position depends on the distribution of mass which can change position when body shape changes.







Center of Mass (COM)

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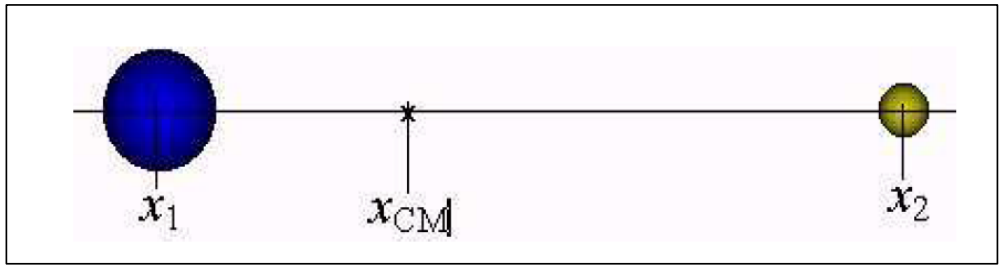
Center of Mass Equation

In one Dimension



- For two masses m_1 and m_2, the center of mass is at:

$$X_{CM} = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2}$$

- For many particles, the center of mass can be written as:

$$X_{CM} = \frac{\sum_{i=1}^{n} m_i x_i}{\sum_{i=1}^{n} m_i}$$

Center of Mass (COM)

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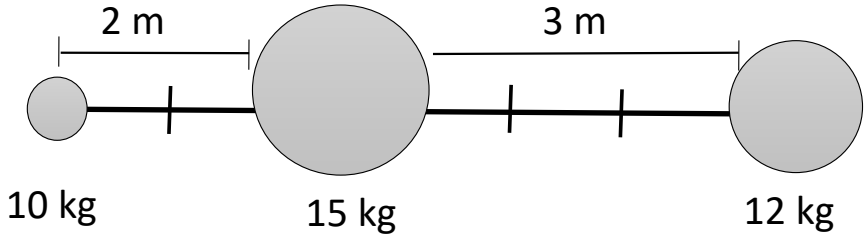
Example: three children's stand in the same line in playground to play football the weight of first boy was 10 kg and the second boy was 15 kg and stand in 2m from first boy while the weight of last boy was 12 kg and stand in 3 m from second boy. Find the center of mass of three children?

Solution:

$$X_{CM} = \frac{m_1x_1 + m_2x_2 + m_3x_3}{m_1 + m_2 + m_3}$$

$$X_{CM} = \frac{(10\ kg*0m)+(15\ kg*2m)+(12\ kg*5m)}{10\ kg+15\ kg+12\ kg}$$

$$X_{CM} = \frac{90}{37}\ \text{m} = 2.432\ \text{m}$$



Center of Mass (COM)

In 3 dimensions the same equations apply

$$\mathbf{X_{cm}} = \frac{\sum_{i=1}^{n} m_i x_i}{\sum_{i=1}^{n} m_i} \quad , \quad y_{cm} = \frac{\sum_{i=1}^{n} m_i y_i}{\sum_{i=1}^{n} m_i} \quad , \quad z_{cm} = \frac{\sum_{i=1}^{n} m_i z_i}{\sum_{i=1}^{n} m_i}$$

Example: Find the center of mass of a system of three particles:

particle	Mass (kg)	X(cm)	Y (cm)
1	1.2	0	0
2	2.5	140	0
3	3.4	70	121

Answer:

$$\mathbf{X_{cm}} = \frac{\sum_{i=1}^{n} m_i x_i}{\sum_{i=1}^{n} m_i} = \frac{m_1 x_1 + m_2 x_2 + m_3 x_3}{m_1 + m_2 + m_3} = \frac{1.2*0+2.5*140+3.4*70}{1.2+2.5+3.4} = 83 \text{ cm}$$

$$y_{cm} = \frac{\sum_{i=1}^{n} m_i y_i}{\sum_{i=1}^{n} m_i} = \frac{m_1 y_1 + m_2 y_2 + m_3 y_3}{m_1 + m_2 + m_3} = \frac{1.2*0+2.5*0+3.4*121}{1.2+2.5+3.4} = 58 \text{ cm}$$

Stability

The most important formations related to stability

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❖ **Base of Support (BOS)**: The area beneath and between the points of contact an object or person has with the ground.

- The BOS area can be changed.
- larger BOS area is typical more stable positions as shown in fig. (1).
- in humans, wide BOS is usually accompanied by low CG as shown in fig. (2).

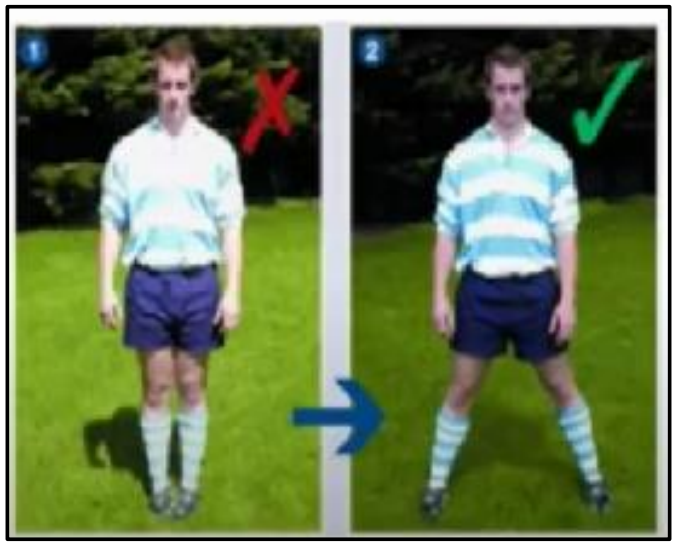

Fig.(1)

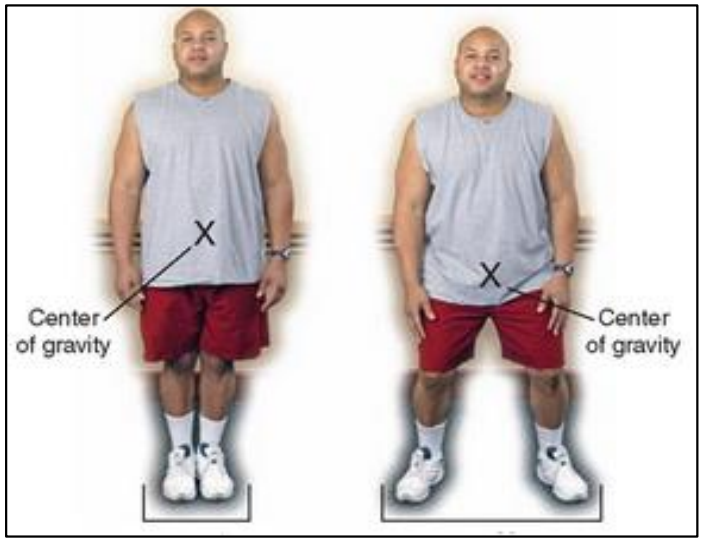

Fig.(2)

Stability

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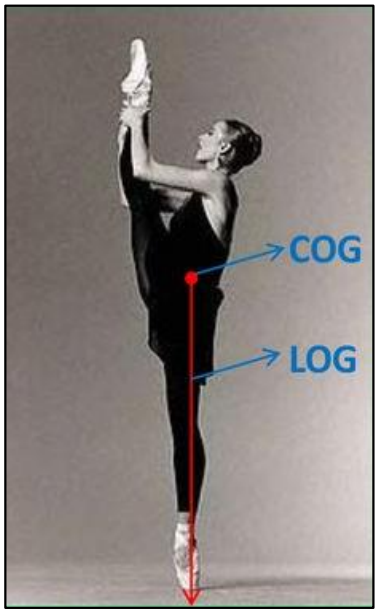
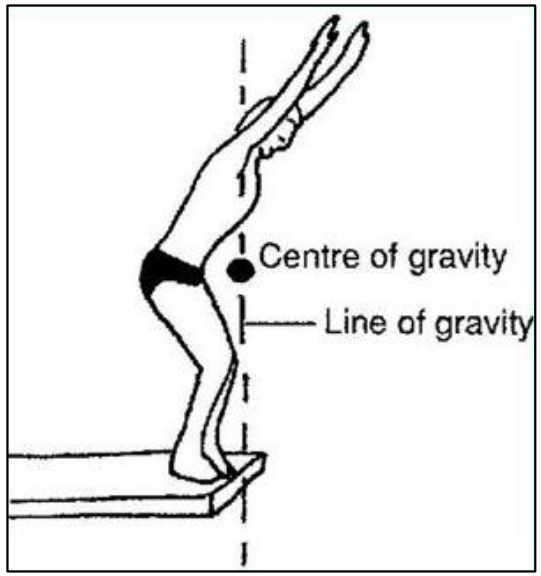
❖ **Line of gravity (LOG)**: This is an imaginary line which passes vertically from the center of gravity to the ground below an object.

- The LOG is always vertical.
- the LOG must outside the base of support to initiate or continues movement.
- the further away the LOG from the BOS, the greater the tendency to move in that direction.





Stability

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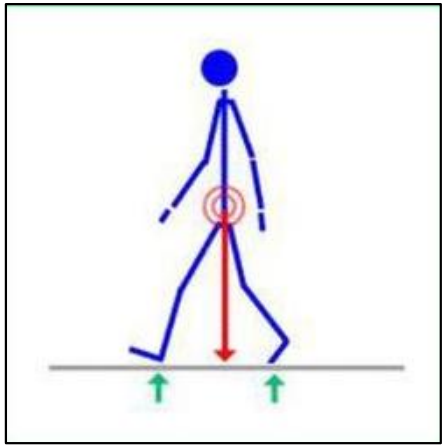
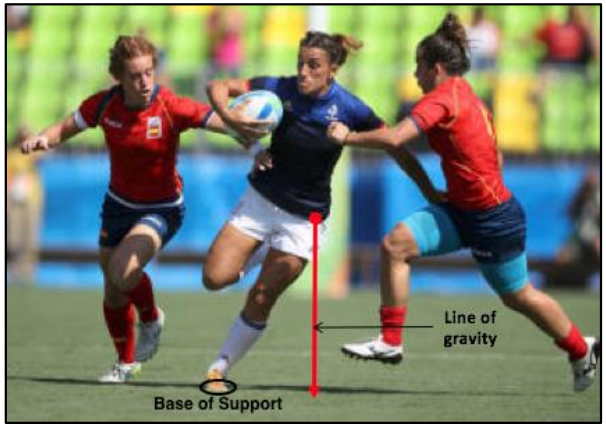
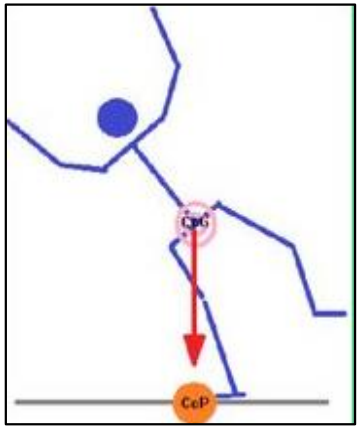
Notes:

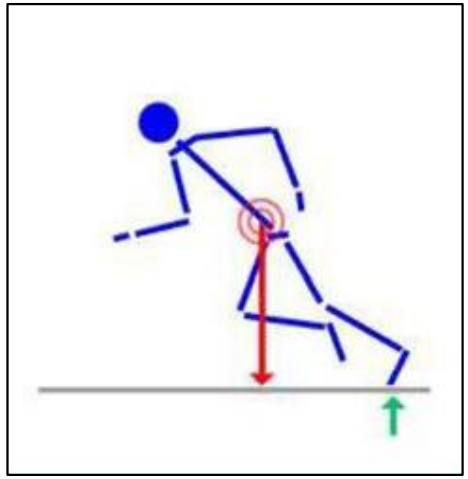
- If the line of gravity falls within the base of support then an object will be more stable.



- if the line of gravity falls outside the base of support then the object will be unstable and fall over.







Stability

❖ **Mass:** the greater the mass of the body, the greater will be its stability.

for example: carrying weight in both hands will increase stability than in case of carrying a weight in one hand .

Stability

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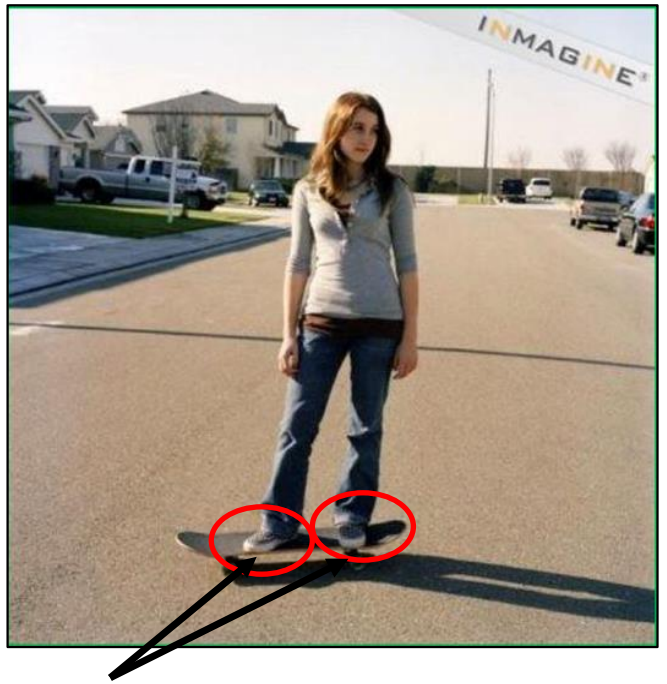
There are 4 main factors that effect the stability of a body including:

1. Center of Mass (COM): the lower the centre of mass, the higher the stability.
2. Line of gravity (LOG): if the line of gravity is central to the base of support, stability is increased.
3. base of support (BOS): the larger the base of support, the higher the stability.
4. Mass: stability is increased with increased mass

Example: What could this girl do to make herself more stable on the skateboard? Describe how she would achieve this?

Answer:

1. Base of support its OK no need more open feet.
2. center of mass must be lower closer to base of support so the upper part of body is bend forward with a slight drop to the bottom.
3. line of gravity must be falls within the base of support to initiate or continues movement and central to the base of support, so stability increased.



Base of support

Stability

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Example: 1. which player is in a more stable position? Why?

2. Which player is less stable ? Why?

Answer:

1. Person 1 is more stable because:

a. Center of mass is slow closer to base of support.

b. line of gravity is vertical and central to the base of support.

c. Base of support the large area of base of support.

Depend on above reasons the person 1 is more stable.

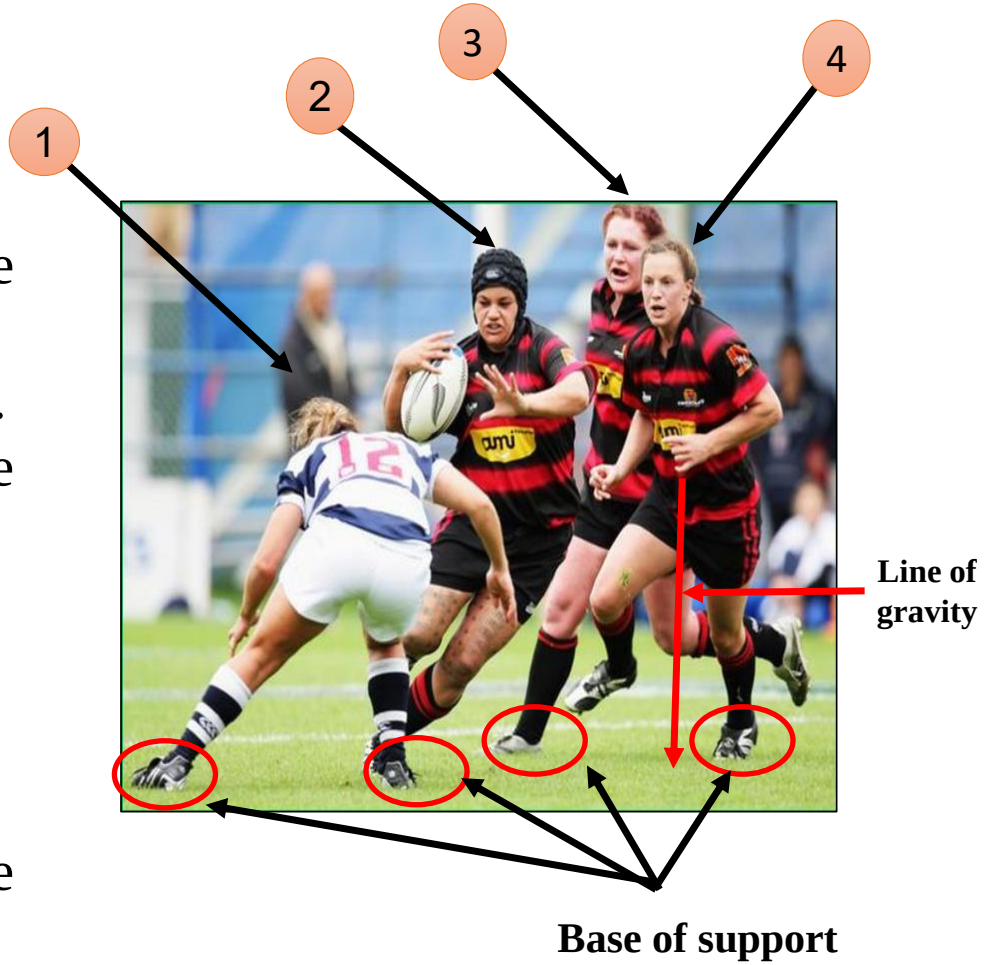
2. Person 2 is less stable because:

a. Center of mass is far to base of support.

b. line of gravity falls out side of base of support.

c. Base of support is small area

3. Persons 3&4 unstable because small area of base of support.



Stability

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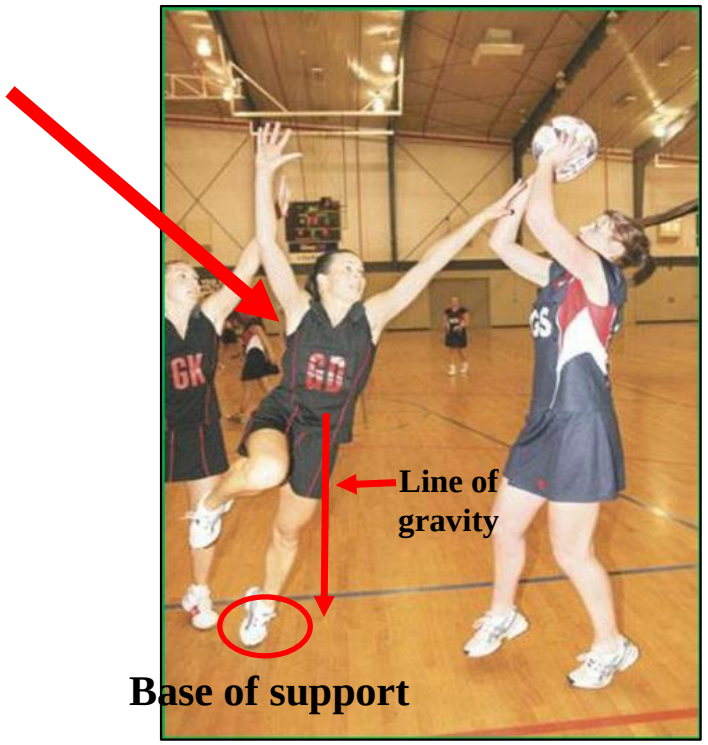
Example: Give 3 reasons why player GD is unstable?

Answer:

a. Center of mass is far to base of support.

b. line of gravity out side of base of support.

c. Base of support is small area



Stability

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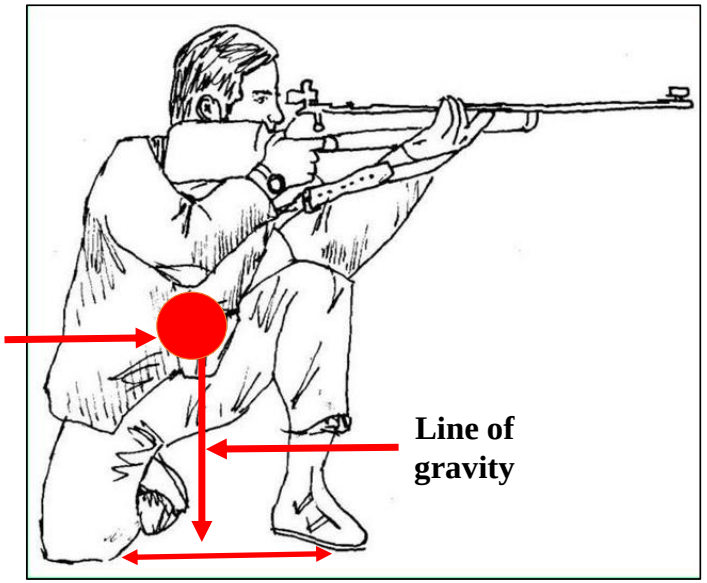
Example: why is this man in a stable position to make a shot?

Answer:

a. Center of mass is slow closer to base of support.
b. line of gravity is vertical and central to the base of support.
c. Base of support the large area of base of support



Base of support

Stability

Example: what of these two people is more stable? why?

Answer:

For two people it can see:

a. Center of mass is slow closer to base of support.
b. line of gravity is vertical and central to the base of support.
c. Base of support the large area of base of support.

But **large man** is more stable than child because **has high mass.**

The End of Lecture