Laws of Motion and Physical Activities

Kinesiology
RHS 341
Lecture **5**
Dr. Einas Al-Eisa

Spatial change in **position**:

Distance	**Displacement**
May or may not be a straight line (the actual length of the path traveled)	Measured in a straight line from one position to the next (how far the object moved & direction)
Scalar quantity	**Vector** quantity
Describes only how far an object moves	Describes the magnitude & **direction** of the change in position

Spatial change in **position**

- Example: running
  - Distance is the actual length of the path traveled
  - Displacement is a straight line between the start and finish of the race

Spatial change in **position**

- An object may have traveled a distance of 10 meters along a linear path in 2 or more directions, but be displaced from its original position by 6m.

- Displacement is defined both by how far the object has moved from its starting position and by the direction it moved.

The **time** rate of change in position:

Speed	Velocity
Scalar quantity	Vector quantity
Describes only magnitude	Describes magnitude & **direction**
$\text{Speed} = \frac{\text{distance}}{\text{time}}$	$\text{Velocity} = \frac{\text{displacement}}{\text{time}}$

Temporal change

- In everyday use, the terms speed and velocity are interchangeable.

- **Speed** = the distance traveled by the time it took to travel.

- In biomechanics, velocity is generally of more interest than speed.

Acceleration

- In human motion, the velocity of a body or a body segment is rarely constant
- **Acceleration** = the rate of change in velocity with respect to time

Acceleration

- The rate at which velocity changes can be related to the forces that cause movement
- Acceleration refers to both increasing and decreasing velocities
- Vector quantity

Acceleration

- Example: runners change their velocity at different intervals throughout the race
  (a runner may run 300m in 65s, but a detailed analysis would reveal that the runner increased and decreased his velocity throughout the race)

There are 2 types of motion

Linear motion (translatory) = Motion along a line

Angular motion (rotatory) = Motion around an axis

Angular motion of joints produce the linear motion of walking

Newton’s laws of motion

- Provide the link between cause and effect that forms the basis for most analyses of human movement in biomechanics

- Explain the characteristics of motion

1) Law of Inertia

- “A body at rest tends to remain at rest unless acted on by a force”
- “A body in motion tends to remain in motion at the same speed in a straight line unless acted on by a force”

1) Law of Inertia

- **Inertia** of an object is used to describe its resistance to motion
- Inertia is directly related to mass

- **Mass** = the measure of the amount of matter that constitutes an object and is expressed in kilograms
- Mass is always constant (regardless of where it is measured)

1) Law of Inertia

- The greater the mass of a body →
  the greater its inertia →
  the harder it is to move it or change its current motion (accelerate or decelerate)

1) Law of Inertia

- Force is required to change inertia
- An individual with a greater mass will have to generate larger **forces** to overcome inertia and generate or change acceleration

1) Law of Inertia

- If an object is subjected to an external force that can overcome the inertia, the object will be either positively or negatively accelerated
- In humans, muscles produce the force necessary to start motion, stop motion, accelerate or decelerate motion, or change the direction of motion

1) Law of Inertia Examples

- A sprinter at the starting position must apply considerable force to overcome resting inertia
- A runner must apply considerable force to overcome moving inertia and stop (before hitting the wall!!)
- Balls thrown require considerable force to stop

1) Law of Inertia Application

- Any activity that is carried out at a steady pace in a consistent direction will conserve energy (e.g., walking, jogging, dancing)

- Any activity that is carried out at an irregular pace in different directions will be costly in energy expenditure and fatiguing (e.g., basketball, volley ball)

2) Law of Acceleration

- “A change in the acceleration of a body occurs in the same direction as the force that caused it”

- “The change in **acceleration** is directly proportional to the **force** causing it and inversely proportional to the **mass** of the body”

2) Law of Acceleration

- Force = Mass * Acceleration

- When analyzing the forces acting on a body, it is important to take the direction of forces into account

- If the forces counteract each other →

  the net force is zero →

  the acceleration will also be zero

2) Law of Acceleration Application

- Strong muscular force is necessary to attain speed in moving the body
- Greater force is required to accelerate a body with heavier mass
- The force required to run at medium speed is less than the force required to run at high speed

2) Law of Acceleration Examples

- Greater force is required to accelerate a football compared to a baseball because of their mass difference

- A much greater force is required from the muscles to accelerate an 80kg man than to accelerate a 50kg man to the same running speed

3) Law of Reaction

"For every action, there is an equal and opposite reaction"

3) Law of Reaction

- Forces never act in isolation, but always in pairs.

- Example: a person landing from a jump exerts a downward force on the earth, and the earth exerts an equal and opposite force on the person (to control the landing) known as ***"ground reaction force"***

3) Law of Reaction

- Walking:
  - Action: the force exerted by the feet on the ground (down and backward)
  - Reaction: the force of the ground or the *Ground reaction force* (up and forward)

- While the action force and the reaction force are equal, the effect on the individual is greater than the effect on the earth (because the earth is more massive than the individual)

3) Law of Reaction

- In human movements, the action force is generated by the person on the ground, and the reaction force generally produces the desired movement

3) Law of Reaction Example

- Is it easier to run on a hard track or a sandy beach?

- The track resists the runner’s force, and the reaction drives the runner ahead.
- But, the sand dissipates the runner’s force, and the reaction force is reduced with a loss in forward force and speed.