Basic Biomechanics II

DEA 3250/6510

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Definitions

- Scalar quantity – quantity with magnitude only (e.g. length, weight)
- Vector quantity – quantity with magnitude + direction (e.g. lifting a box)
- Coplanar – vectors operating in the same plane.

Vector Addition

- Tip-to-tail method – simple method using graphic representation of vectors.
  - Tip of 1st vector coincides with tail of the 2nd vector.
  - Tip of 1st vector is joined to tail of 2nd vector to create the resultant.

Vector Addition :

Tip-to-tail method

Vector Subtraction :

Tip-to-tail method

Vector Addition : >2 vectors

Force

- Force – mechanical disturbance or load (e.g. push, pull, throw, kick, hold, squeeze etc.)

LAWS OF MOTION

- Newton's 1st Law – a body that is originally at rest will remain at rest, or a body moving with constant velocity in a straight line will maintain its motion until an external resultant force is applied.

Inertia

- Inertia – tendency for a body to maintain its state of rest or uniform motion in a straight line.
- The more inertia an object has the harder it is to start moving it from rest.

LAWS OF MOTION

- Newton's 2nd Law – Acceleration of a body is directionally proportional to the net force acting on the body and inversely proportional to its mass.

LAWS OF MOTION

- Newton's 3rd Law - for every action there is an equal and opposite reaction.

Definitions

Units of Force

- SI system:
  - Newton (N) [kilogram_meter/second^2]
- CG system (cgs)
  - Dyne (dyn) [gram_centimeter/second^2]
- British system (Imperial system)
  - Pound (lb) [slug_foot/second^2]

1 N = 10^5 dyn = 0.225 lb f

External Forces

- Hammering a nail, pushing a cart, kicking a ball etc. are all examples of external forces

External Forces

- Compression force (e.g. pushing the hand against the edge of an object).

External forces

- Newton's 3rd law of motion.

Normal force

- Normal force acts perpendicular to a surface e.g. book on desk, sitting on chair, leaning back against a wall etc.

Tangential forces

- Force applied on a surface in a direction parallel to the surface (e.g. frictional forces).

Tensile force

- Force that cause stretching/ elongation of a body (muscles produce tensile forces).

Collinear Forces

- All forces have a common line of action (e.g. tug of war, tendons).

Concurrent Forces

- Lines of action of force have a common point of intersection (e.g. surgical traction system).

Parallel Forces

- Lines of action are parallel to each other (e.g. flexed arm).

Compressive Forces

- Compressive forces depend on the load and the area.

Gravitational Force

W = weight
m = mass
g = gravity

$$W = mg$$

SI = 9.81 m/s^2
cgs = 981 cm/s^2
Brit = 32.2 ft/s^2

Pressure

- Pressure measures the intensity of distributed loads (e.g. sitting on chair, foot on floor, finger on key etc.

Units of Pressure

- SI system:
  - Pascal (Pa) [kilogram/second^2 _meter]
- CG system (cgs)
  - Gram/centimeter_second^2 or dyne/cm^2
- British system (Imperial system)
  - Pound per square foot (lb/ft^2)

Center of Gravity

- Distributed load over a surface can be represented by a single force (equivalent force or concentrated load).
- Line of action of this force passes through a point called the center of gravity or center of mass.

Center of Gravity

- Center of gravity plays an important role for lifting boxes.

Frictional forces

- Frictional force measures the resistance between the surfaces of sliding bodies in contact with each other.
- Usually measured as the coefficient of friction.

MOMENTS (TORQUE)

- Force applied to an object can translate, deform and/or rotate the object (e.g. opening a door – torque – rotational force at hinges).

MOMENTS (TORQUE)

- When a perpendicular force is applied on a lever arm at some distance from its axis of rotation (fulcrum) there is a rotational tendency that is termed torque or moment.
- Torques generated by the body translate muscle contractions into mechanical work (e.g. movements of the fingers, arms, legs etc.)

POSITIVE WORK

- Positive Work occurs whenever the product of muscle force and the force arm (F x FA) > the product of the resistance and

resistance arm (R x RA), and movement occurs (dynamic torque). Positive work occurs in situations such as lifting a heavy bag or box.

NEGATIVE WORK

- Negative Work occurs whenever the force to move a load > muscle strength and muscle extension occurs. Negative work occurs in situation such as lowering a bag or box that is too heavy to lift.

STATIC TORQUE

- Static Torque occurs whenever the product of muscle force and the force arm (F x FA) = the product of the resistance and resistance arm (R x RA). Static torque occurs in situations such as isometric exercises.

Calculating Simple Torque

- The formula for simple torque is

$T = F \times D\perp$ where T = torque

orce = f F

$D \perp$ = perpendicular distance from axis of rotation

Example

- Calculate the simple torque when a straight-arm lift is used to raise a 1Kg bag of sugar from a counter-top to a shelf 1 foot above the counter-top? Assume a shoulder-hand length of 0.5 m.

LEVER SYSTEMS

- First class lever – fulcrum (center of rotation A) is located between the load (resistance R) and the force (muscle - F).
  - Resistance arm (RA) = distance from R to A
  - Force arm (FA) = distance from F to A
- When FA > RA there is a mechanical advantage.

First Class Lever System

- When looking down a microscope:
  - Fulcrum - atlanto-occipital joint connecting head and spinal column
  - Resistance – mass of head
  - Force – contractions of trapezius muscles at back of neck and shoulders
- When head is very flexed RA > FA (no mechanical advantage)
- Microscope workers report neck and shoulder pain.

Second Class Lever System

- In a second class lever system the fulcrum is at one end of the force arm, and FA is always > RA.
- Only a few examples of such systems in the body (e.g. opening mouth when teeth are stuck together with gooey toffee).

Third Class Lever System

- Many examples of third class lever systems in the body. Here RA always > FA, so systems are at a mechanical disadvantage.

Third Class Lever System

- Lifting an object using the hand and pivoting at the elbow is an example of a third class lever system.