#### Basic Biomechanics II DEA 3250/6510 Professor Alan Hedge

## 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 1<sup>st</sup> vector coincides with tail of the 2<sup>nd</sup> vector.
  - Tip of 1<sup>st</sup> vector is joined to tail of 2<sup>nd</sup> 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 1<sup>st</sup> 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 2<sup>nd</sup> 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 3<sup>rd</sup> Law - for every action there is an equal and opposite reaction.

#### Definitions

#### Units of Force

- SI system:
  - ◆ Newton (N) [kilogram\_meter/second<sup>2</sup>]
- CG system (cgs)
  - ◆ Dyne (dyn) [gram\_centimeter/second<sup>2</sup>]
- British system (Imperial system)
  - Pound (Ib) [slug\_foot/second<sup>2</sup>]

 $1 \text{ N} = 10^5 \text{ dyn} = 0.225 \text{ lb f}$ 

## **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 3<sup>rd</sup> 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

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SI = 9.81 m/s<sup>2</sup>
cgs = 981 cm/s<sup>2</sup>
Brit = 32.2 ft/s<sup>2</sup>
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#### 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<sup>2</sup>\_meter]
- CG system (cgs)
  - Gram/centimeter\_second<sup>2</sup> or dyne/cm<sup>2</sup>
- British system (Imperial system)
  - Pound per square foot (lb/ft<sup>2</sup>)

#### 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

orc<del>e</del> 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.