بايوميكانيك

قسم تقنيات العلاج الطبيعي

المرحلى الاولى

اعداد

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قسم تقنيات العلاج

لا Biomechanics

الميكانيكا الحيوية

لا First Class

لا الدرجة الأولى

Biomechanics is the study of how the systems and structures of biological organisms react to various forces and external stimuli. Biomechanics often refers to the study of how the skeletal and musculature systems work under different conditions.

الميكانيكا الحيوية هي دراسة كيفية تفاعل أنظمة وهياكل الكائنات البيولوجية مع القوى المختلفة والمحفزات الخارجية. تشير الميكانيكا الحيوية غالبًا إلى دراسة كيفية عمل أنظمة الهيكل العظمي والعضلات في ظل ظروف مختلفة.

GENERAL TERMS

شروط عامة

The following general terms are common to mechanics in general, although they are also used widely in biomechanics:

المصطلحات العامة التالية شائعة في الميكانيكا بشكل عام، على الرغم من أنها تستخدم أيضًا على نطاق واسع في الميكانيكا الحيوية:

Units : we use SI units (System International Units) which use four fundamental quantities (length, mass, time and force) as below :

الوحدات : نستخدم وحدات SI (وحدات النظام الدولي) والتي تستخدم أربع كميات أساسية (الطول والكتلة والوقت والقوة) على النحو التالي:

Length meter (m)

الطول متر (م)

Mass Kilogram (Kg)

كيلوغرام الكتلة (كجم)

Time second (s)

الوقت ثانية (ث)

Force Newton (N)

قوة نيوتن (ن)

Peak – the peak value of any measurement is the point with the greatest magnitude in a data set. Peak values are often seen in biomechanics, such as when measuring joint angles (the maximum joint angle reached).

الذروة – قيمة الذروة لأي قياس هي النقطة ذات الحجم الأكبر في مجموعة البيانات. غالبًا ما تُرى قيم الذروة في الميكانيكا الحيوية، كما هو الحال عند قياس زوايا المفصل (الحد الأقصى لزاوية المفصل التي تم الوصول إليها).

Mean – the mean value of any measurement is an average of a data set and is calculated by taking the sum of all the values and dividing this number by the number of values. Mean values are also commonly used in biomechanics, such as when measuring joint moments.

المتوسط – القيمة المتوسطة لأي قياس هي متوسط مجموعة البيانات ويتم حسابها عن طريق أخذ مجموع كل القيم وتقسيم هذا الرقم على عدد القيم. تُستخدم القيم المتوسطة أيضًا بشكل شائع في الميكانيكا الحيوية، كما هو الحال عند قياس العزوم المشتركة.

Vector – a vector is a quantity that has a direction as well as a magnitude. Example of vector quantities are velocity, acceleration, force and moment.

المتجه - المتجه هو الكمية التي لها اتجاه وكذلك حجم. ومن أمثلة الكميات المتجهة السرعة والتسارع والقوة والعزم.

Scalar – a scalar is a quantity that has no direction but only a magnitude. Examples of scalar quantities are time, volume, density and mass.

العددية - العددية هي الكمية التي ليس لها اتجاه ولكن حجمها فقط. ومن أمثلة الكميات العددية الزمن والحجم والكثافة والكتلة.

Component – components of vectors are used to help make calculations of vectors easier. Every vector in mechanics or biomechanics can be broken down into 3 orthogonal components, which are labelled as x, y, and z. Orthogonal means that each component acts at right angles to the others. In biomechanics, these three orthogonal components refer to the frontal, sagittal and transverse planes, respectively.

المكون - يتم استخدام مكونات المتجهات للمساعدة في تسهيل حسابات المتجهات. يمكن تقسيم كل متجه في الميكانيكا أو الميكانيكا الحيوية إلى 3 مكونات متعامدة، والتي تسمى x و y و z. المتعامد يعني أن كل مكون يعمل بزوايا قائمة على الآخرين. في الميكانيكا الحيوية، تشير هذه المكونات المتعامدة الثلاثة إلى المستويات الأمامية والسهمية والعرضية، على التوالي.

Resultant – the resultant vector is the vector calculated when summing together other vectors, often in the form of components but also in the form of two or more vectors acting in different directions on the same

المحصلة - المتجه الناتج هو المتجه الذي يتم حسابه عند جمع ناقلات أخرى معًا، غالبًا في شكل مكونات ولكن أيضًا في شكل متجهين أو أكثر يعملان في اتجاهات مختلفة على نفس الشيء

object. For example, during running, there are forces acting both vertically and horizontally and also both

هدف. على سبيل المثال، أثناء الجري، هناك قوى تؤثر عموديًا وأفقيًا، وكذلك كلاهما

forwards (propulsive) and backwards (braking) but ultimately there is a resultant force that moves the runner

للأمام (الدفع) والخلف (الكبح) ولكن في النهاية هناك قوة محصلة تحرك العداء

forwards.

إلى الأمام.

Kinematics is the branch of mechanics that deals with the motion of a body without reference to force or mass. Kinematics describes the motion of a joint in three planes.

الكينماتيكا هي فرع من الميكانيكا الذي يتعامل مع حركة الجسم دون الرجوع إلى القوة أو الكتلة. يصف علم الحركة حركة المفصل في ثلاث طائرات.

Kinetics is the branch of mechanics that deals with the motion of a body under the action of forces and moments.

الحركية هي فرع من الميكانيكا الذي يتعامل مع حركة الجسم تحت تأثير القوى واللحظات.

Types of Motion

أنواع الحركة

the two basic types of motion are rotation and translation. Rotation is motion about an axis, causing points on the rotating body to travel different distances depending upon their distance from the point of rotation. Translation produces a linear movement in which all points in the body travel the same distance regardless of their location in the body. Most cartilaginous and fibrous joints allow translation, or linear movement. Synovial joints, on the other hand, allow both rotation and translation.

النوعان الأساسيان للحركة هما الدوران والترجمة. الدوران هو الحركة حول محور، مما يجعل النقاط الموجودة على الجسم الدوار تتحرك مسافات مختلفة اعتمادًا على المسافة التي تفصلها عن نقطة الدوران. تنتج الترجمة حركة خطية تتحرك فيها جميع نقاط الجسم نفس المسافة بغض النظر عن موقعها في الجسم. تسمح معظم المفاصل الغضروفية والليفية بالترجمة، أو الحركة الخطية. من ناحية أخرى، تسمح المفاصل الزليلية بالتدوير والترجمة.

Location of Motion

موقع الحركة

Motion cannot be measured independently, it is relative to an observer. So if a body is changing its position and location with time with respect to the observer, then it is said to be in motion.

لا يمكن قياس الحركة بشكل مستقل، فهي نسبية بالنسبة للمراقب. فإذا كان الجسم يتغير موضعه وموقعه مع الزمن بالنسبة للراصد، يقال أنه متحرك.

For example, the door of a moving train is in motion with respect to an observer standing on the ground. But, it is at rest with respect to a passenger sitting in the moving train.

على سبيل المثال، باب قطار متحرك يتحرك بالنسبة لمراقب يقف على الأرض. ولكنها في حالة سكون بالنسبة إلى راكب يجلس في القطار المتحرك.

Direction of Motion

اتجاه الحركة

The "direction of motion" is basically the direction of the object's displacement during a very small time interval.

"اتجاه الحركة" هو في الأساس اتجاه إزاحة الجسم خلال فترة زمنية صغيرة جدًا.

Velocity: velocity is the rate of change of position of an athlete (in m/s), which is the displacement

السرعة المتجهة: السرعة هي معدل تغير موضع اللاعب (بالمتر/الثانية)، وهي الإزاحة

divided by time. It is a vector quantity (meaning that it has a direction associated with it) and speed is

مقسمة على الوقت. إنها كمية متجهة (بمعنى أن لها اتجاه مرتبط بها) والسرعة هي

its scalar equivalent.

معادلته العددية.

Range of motion (ROM):the displacement in angular movement is generally measured by reference to

نطاق الحركة (ROM): يتم قياس الإزاحة في الحركة الزاوية بشكل عام بالرجوع إلى

ROM, which can be reported in either degrees or radians.

ROM، والتي يمكن الإبلاغ عنها إما بالدرجات أو بالراديان.

Center of mass (COM)– the center of mass is the unique point within an object. It is the average position of all the parts of the system, weighted according to their masses. For simple rigid objects with

مركز الكتلة (COM) – مركز الكتلة هو النقطة الفريدة داخل الجسم. إنه متوسط موضع جميع أجزاء النظام، مرجحًا حسب كتلتها. للأشياء الصلبة البسيطة مع

uniform density, the center of mass (COM) is located at the centroid.

كثافة موحدة، مركز الكتلة (COM) يقع في النقطه الوسطى.

Definition of Forces

تعريف القوات

Force – is the action of one body on another. Force equals mass times acceleration (F = ma) and where mass

القوة - هي تأثير جسم على جسم آخر. القوة تساوي الكتلة مضروبة في التسارع (F = ma) وحيث الكتلة

(kg) and acceleration (m/s2) are expressed in standard international (SI) units, force is expressed in Newtons

(كجم) والتسارع (م/ث2) يتم التعبير عنهما بوحدات دولية قياسية (SI)، ويتم التعبير عن القوة بالنيوتن

Force of Gravity

قوة الجاذبية

the force of gravity acts between the earth surface and any object

تعمل قوة الجاذبية بين سطح الأرض وأي جسم

Analysis of Forces

Analysis of forces into a pair of perpendicular components is very important subject to be studied in order to have a full knowledge about the effect and distribution of forces on rigid bodies which are remaining of rest.

Analysis of forces into a pair of perpendicular components as shown in figure (5):

F_x: The component of **F** for the x- axis **fx** المركبة الافقية

F_y: The component of **F** for the y-axis **fy** المركبة العمودية

$$\sin\theta = \frac{F_y}{F}$$

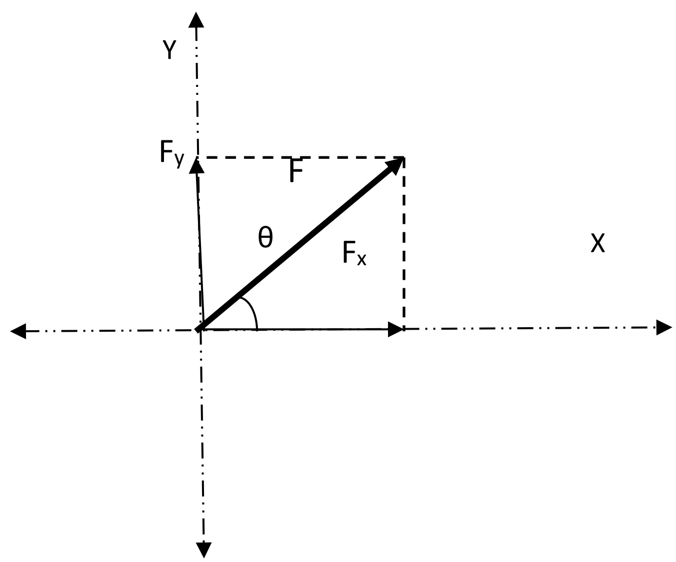
$$\cos\theta = \frac{F_x}{F}$$

Or

$$F_y = F\ \sin\theta$$

And

$$F_x = F\cos\theta$$



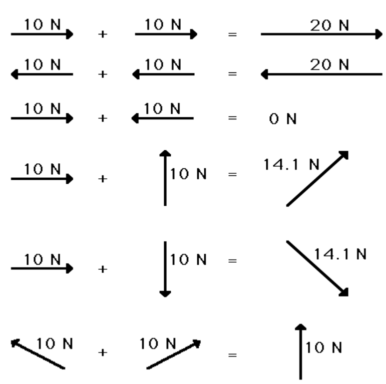
Resultant of Concurrent Forces:

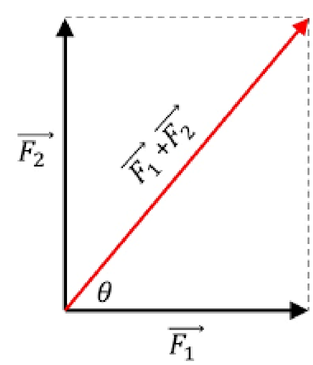
$$\mathbf{R}_x = \sum \mathbf{F}_x$$

$$\mathbf{R}_y = \sum \mathbf{F}_y$$

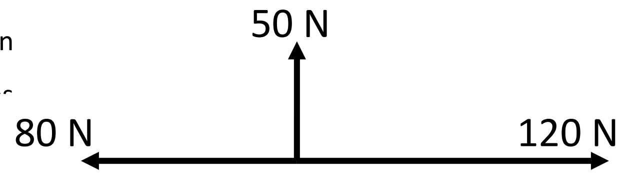
$$\mathbf{R} = \sqrt{\mathbf{R}_x^2 + \mathbf{R}_y^2}$$

$$\boldsymbol{\theta} = \mathbf{tan}^{-1}\frac{\mathbf{R}_y}{\mathbf{R}_x}$$





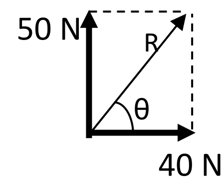
Ex.: find the magnitude (القيمة) and direction (الاتجاه)of resultant (المحصلة) for the forces shown?



Sol:

R_x=120-80 =40 N

R_y=50 N

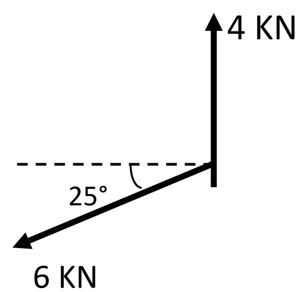


R= $\sqrt{R_x^2 + R_y^2} = \sqrt{(40)^2 + (50)^2}$

$= \sqrt{1600 + 2500} = \sqrt{4100} = 64\ N$

$\theta = \tan^{-1}(\frac{R_y}{R_x}) = \tan^{-1}(\frac{50}{40}) = \tan^{-1}(1.25) = 51.34\ degrees$

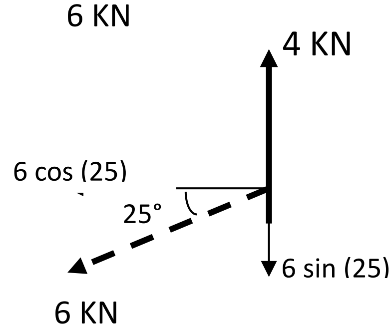
Ex.: find the magnitude and direction of resultant for the forces shown?



Sol:

R_x = - 6 cos (25) = - 5.44 KN

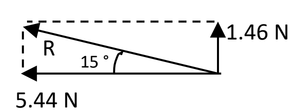
R_y = 4 – 6 sin (25) =1.46 KN



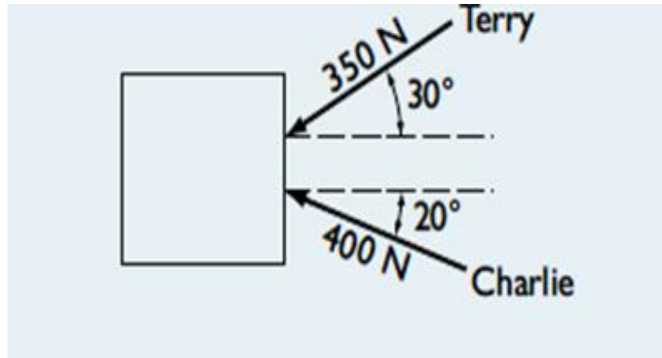
$R = \sqrt{R_x^2 + R_y^2}$

$R = \sqrt{(-5.44)^2 + (1.46)^2} = 5.63\ KN$

$\theta = \tan^{-1}(\frac{R_y}{R_x}) = \tan^{-1}(\frac{1.46}{5.44})$ =15 °



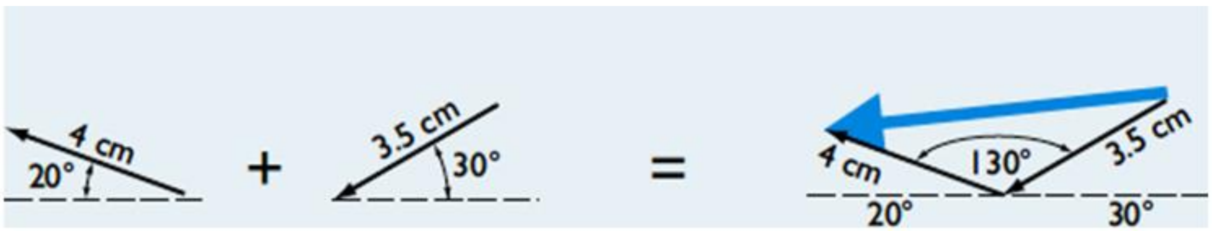
Example



Terry and Charlie must move a refrigerator to a new location. They both push parallel to the floor. Terry with a force of 350 N and Charlie with a force of 400 N. What is the magnitude of the resultant forces produced by terry and Charlie? If the amount of friction force that directly opposes the direction of motion of the refrigerator is 700, will they be able to move the refrigerator?

Graphic solution

Use the scale 1 cm= 100 N to measure the length of the resultant



The length of the resultant is approximately 6.75 cm or 675 N.

Since 675<700, they will not be able to move the refrigerator.

Trigonometric Solution

Given FT=350 N

FC=400 N

$C^2 = A^2 + B^2 - 2(A)(B)COS\ \theta \qquad (\ the\ law\ of\ cosines)$

$$R^2 = 400^2 + 350^2 - 2(400)(350)COS\ 130$$

$$R = 680\ N$$

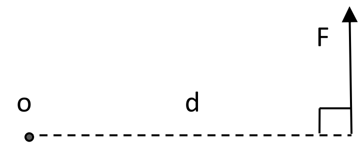
Since 680 < 700, they will not be able to move the refrigerator unless they exert more collective force while pushing at these particular angles.

Moment of a Force

Moment is a rotational tendency when a force tend to rotate a body about an axis.

Moment of force defined as the product of the magnitude of the force by the perpendicular distance (arm) from the point to the action line of the force.

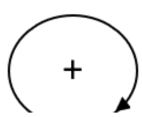
$M = F.d$



The moment is a vector M perpendicular to the plane of the body. To identify the direction of the moment we use the right hind rule (قاعدة اليد اليمنى). The basic unit of moment in SI units are Newton *meters (N.m).

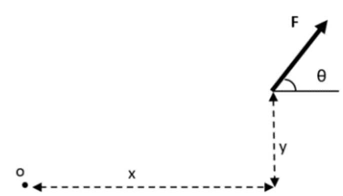
We can use plus sign (+) for clockwise moment and minus sign (-) for counterclockwise moment or vice versa.

يمكننا أن نستخدم إشارة (+) للعزم باتجاه عقارب الساعة والاشارة (-) للعزم باتجاه عكس عقارب الساعة والعكس بالعكس.



Varignon's Theorem:

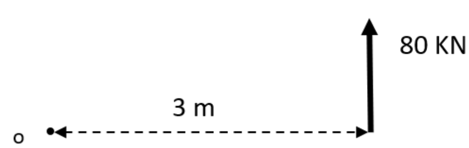
The moment of a force is equal to the moment sum of its components.



From figure (8) we can write:

M_o=F cos(θ) . (y) +(- F sin (θ) . (x))

Ex.: Find the moment of the force 80 KN about the point (o) as shown in the following figure?



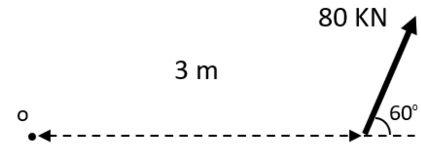
Sol:

$M = F.d$

M= 80 x 3 = - 240 KN.m

ملاحظة : الاشارة السالبة تعني ان العزم باتجاه عكس عقارب الساعة

Ex.: Find the moment of the force **F** about the point (o) as shown in the following figure?

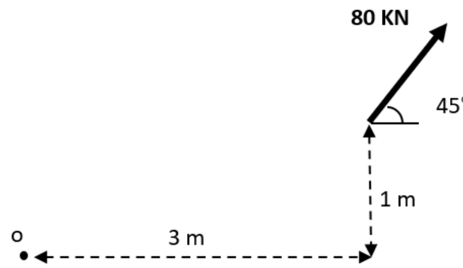


Sol:

$M = F.d$

M= - 80 sin(60) x 3 + 80 cos(60)x 0= - 207.85 KN.m

Ex.: Find the moment of the force 80 KN about the point (o) as shown in the following figure?



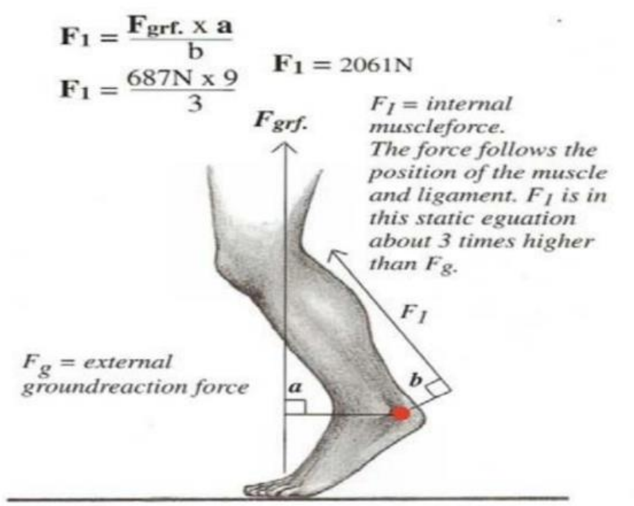
Sol:

From Varignon's Theorem

$M_o = 80\cos 45 * (1) - 80 \sin 45 * (3) = -113.12$ KN.m

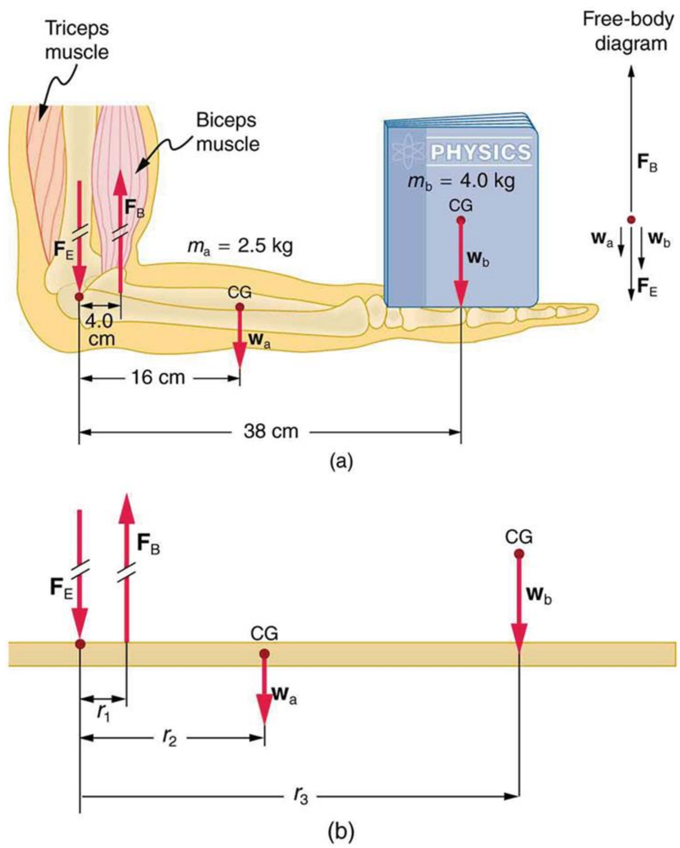
Moment arm of force

for a 70 kg person standing on his toe if a= 9 cm , b=3 cm then the ankles tendon can be calculated



Ex

Forces and Torques in Muscles and Joints Muscles, bones, and joints are some of the most interesting applications of statics. There are some surprises. Muscles, for example, exert far greater forces than we might think. Figure shows a forearm holding a book and a schematic diagram of an analogous lever system. The schematic is a good approximation for the forearm, which looks more complicated than it is, and we can get some insight into the way typical muscle systems function by analyzing it. Muscles can only contract, so they occur in pairs. In the arm, the biceps muscle is a flexor—that is, it closes the limb. The triceps muscle is an extensor that opens the limb. This configuration is typical of skeletal muscles, bones, and joints in humans and other vertebrates. Most skeletal muscles exert much larger forces within the body than the limbs apply to the outside world. The reason is clear once we realize that most muscles are attached to bones via tendons close to joints, causing these systems to have mechanical advantages much less than one. Viewing them as simple machines, the input force is much greater than the output force, as seen in Figure.



Strategy There are four forces acting on the forearm and its load (the system of interest). The magnitude of the force of the biceps is FB; that of the elbow joint is F_E; that of the weights of the forearm is wa, and its load is w_b. Two of these are unknown (F_B and F_E), so that the first condition for equilibrium cannot by itself yield F_B. But if we use the second condition and choose the pivot to be at the elbow, then the torque due to F_E is zero, and the only unknown becomes F_B.

Solution The torques created by the weights are clockwise relative to the pivot, while the torque created by the biceps is counterclockwise; thus, the second condition for equilibrium (netτ =0) becomes

$$r_2 w_a + r_3 w_b = r_1 F_B$$

Note that $\sin\theta = 1$ for all forces, since $\theta = 90°$ for all forces. This equation can easily be solved for F_B in terms of known quantities, yielding

$$F_B = \frac{r_2 w_a + r_3 w_b}{r_1}$$

Entering the known values gives

$$F_B = \frac{(0.160\text{ m})(2.50\text{ kg})(9.80\text{ m/s}^2) + (0.380\text{ m})(4.00\text{ kg})(9.80\text{ m/s}^2)}{0.0400\text{ m}}$$

which yields $F_B = 470$ N

Now, the combined weight of the arm and its load is

$$(6.50\text{ kg})(9.80\text{ m/s}^2) = 63.7\text{ N}$$

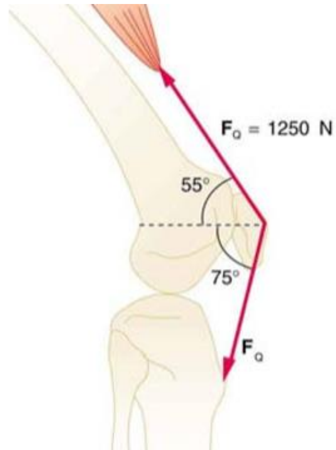
so that the ratio of the force exerted by the biceps to the total weight is

$$\frac{F_B}{w_a + w_b} = \frac{470}{63.7} = 7.38.$$

Discussion This means that the biceps muscle is exerting a force 7.38 times the weight supported.

problem

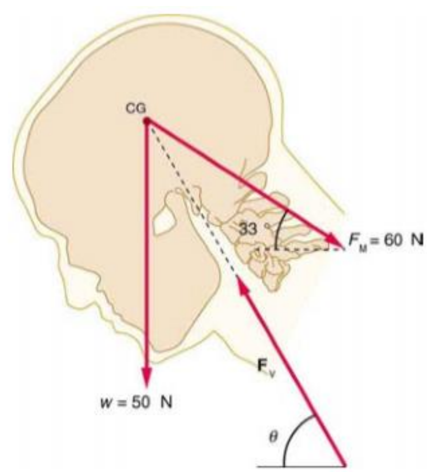
The upper leg muscle (quadriceps) exerts a force of 1250 N, which is carried by a tendon over the kneecap (the patella) at the angles shown in Figure. Find the direction and magnitude of the force exerted by the kneecap on the upper leg bone (the femur).



The knee joint works like a hinge to bend and straighten the lower leg. It permits a person to sit, stand, and pivot.

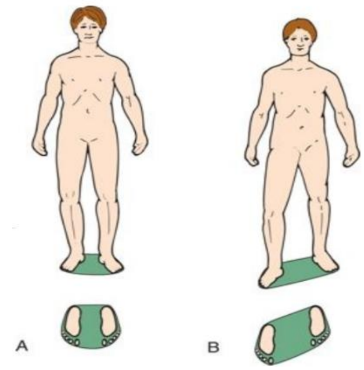
problem

A person working at a drafting board may hold her head as shown in Figure 9.40, requiring muscle action to support the head. The three major acting forces are shown. Calculate the direction and magnitude of the force supplied by the upper vertebrae FV to hold the head stationary, assuming that this force acts along a line through the center of mass as do the weight and muscle force.



Supporting base

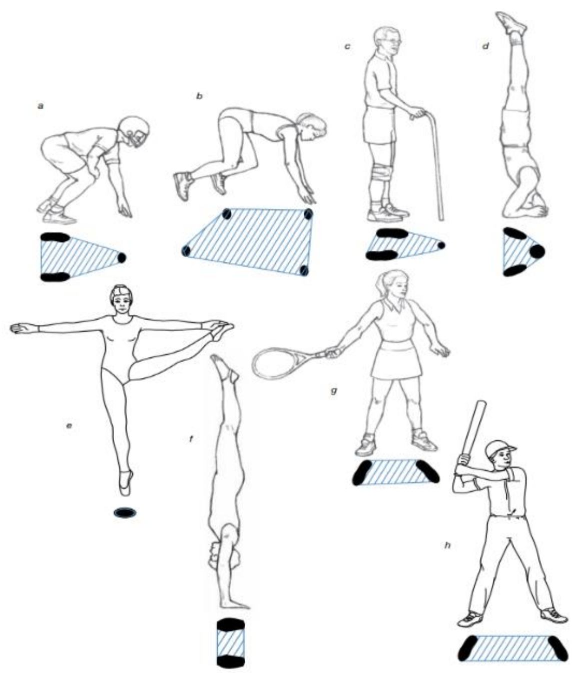
The base of support (BOS) refers to the area beneath an object or person that includes every point of contact that the object or person makes with the supporting surface. These points of contact may be body parts e.g. feet or hands, or they may include things like crutches or the chair a person is sitting in.



The BOS is an important concept to understand an individual's ability to Balance, as balance is defined as the ability to maintain the line of gravity (passing through the Centre of Gravity) within the BOS.

For example, during a single leg balance the BOS is the area of the foot in contact with the surface; however, when a person is standing on two feet, the BOS is the area of both feet and the surface between them.

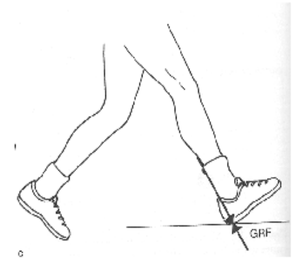
In gait, the base of support has been defined as the horizontal stride width during the double-support phase when both feet are in contact with the ground and the whole-body center of gravity (CG) remains within the BOS. A wide base of support (BOS) has long been believed to be a hallmark of unsteady gait.



Reaction forces

A reaction force is a force that acts in the opposite direction to an action force. Ground reaction force is an example shown in the figure.

Ground Reaction Force



Static Equilibrium

When a body is in Equilibrium**,** the resultant of all forces acting on it is zero. Thus, the resultant force R and the resultant moment M are both zero, and we have the Equilibrium equations:

$$\mathbf{R} = \sum \mathbf{F} = \mathbf{0} \qquad \mathbf{M} = \sum \mathbf{M} = \mathbf{0}$$

$$\sum \boldsymbol{F_x} = \mathbf{0} \qquad \sum \boldsymbol{F_y} = \mathbf{0} \qquad \sum \boldsymbol{M_o} = \boldsymbol{o}$$

A general approach used to solve for forces during static equilibrium is as follows:

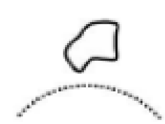
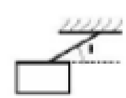
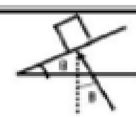
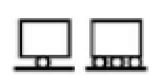
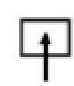
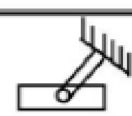
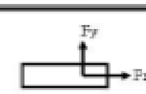
Step 1 Isolate the body of interest.

Step 2 Sketch this body and all external forces (referred to as a free body diagram).

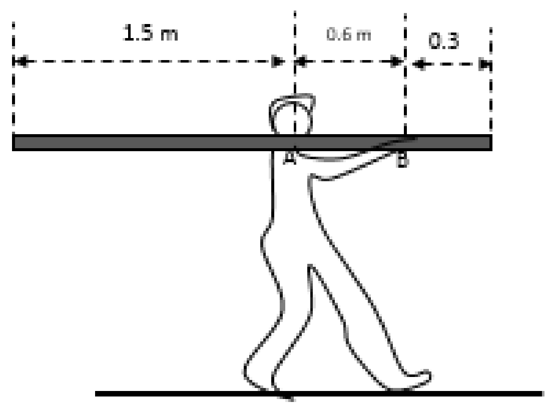
Step 3 Sum the forces and moments equal to zero.

Step 4 Solve for the unknown forces.

Table (1): F.B.D for many types of contacts

The name of the body	The effect of the body	The free body diagram
Erath		
Flexible cables and ropes		
Cantilever beam		
Smooth surface		
Rollers , balls , cylinders		
Smooth pins		

Ex: A carpenter carries A 8 Kg uniform board as shown. What downward force does he lift on his shoulder?

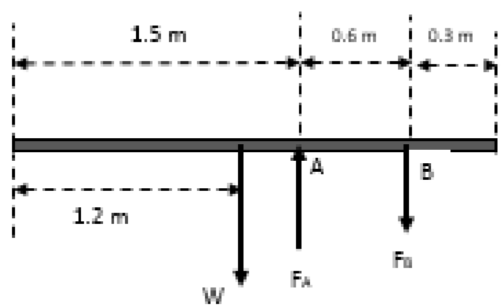


Sol:

The weight of the board W=8*9.81=78.48 N

The length of the board is: 1.5+0.6+0.3=2.4 m

The center of gravity will be in the middle of the board 2.4/2=1.2 m



Taking the moment about B

$\sum M_B = 0$

$F_A * 0.6 - 78.48 * 0.9 = 0$

$$F_A = \frac{70{,}632}{0{,}6} = 117{,}72 \text{ N}$$

Dynamic equilibrium

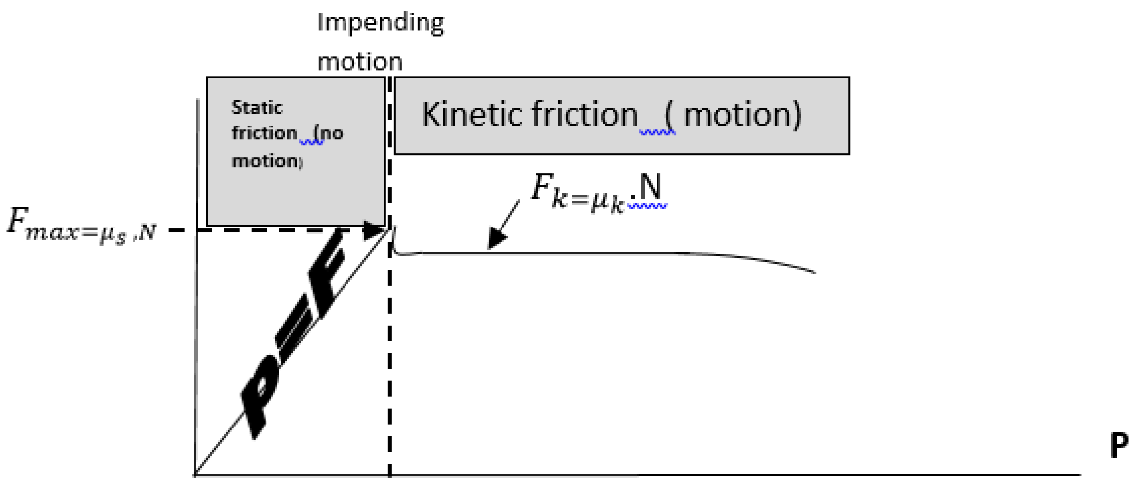
Dynamic equilibrium is when all the forces acting on an object are balanced but the object is moving (it has a velocity). Mechanical equilibrium exists when Newton's 1st Law is true on our system of interest. Newton's first law states that a body will remain at rest or continue in a straight line with a constant velocity unless it is compelled to change by an external force.

In static equilibrium, the velocity is zero but in dynamic equilibrium, the velocity is constant.

Force of friction

Friction is the force that resists motion when the surface of one object comes in contact with the surface of another.

Friction is the tangential forces generated between contacting surfaces.



Static Friction:- the region in the fig. above up to point of slippage or impending motion is called the range of static friction, and in this range the value of static friction force is determined by the equation of equilibrium. This friction force may have any value from zero up to and including the maximum value which proportional to the normal force N. thus we may write:-

$$F_{max} = \mu_s N$$

where μ_s is the proportionality constant, called the coefficient of static friction.

Be aware that the last equation describes only the limiting or maximum value of the static friction force and not any lesser value, thus the equation applies only to where motion is impending with the friction force at its peak value. For a condition of static equilibrium where motion is not impending, the static friction force is $F < \mu_s N$

Kinetic Friction: - After slippage occurs, a condition of kinetic friction accompanies the ensuing motion. Kinetic friction force is usually somewhat less than the maximum static friction force. The kinetic friction force is also proportional to the normal force, thus

$$F_k = \mu_k N$$

Where μ_k is the coefficient of kinetic friction. Also we can write

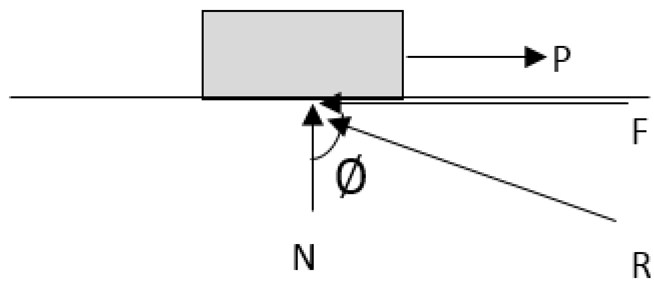
$\mu_k < \mu_s$

Friction on Horizontal surface

$F_s = R \sin \emptyset$

$\tan \emptyset = \frac{F_s}{N}$

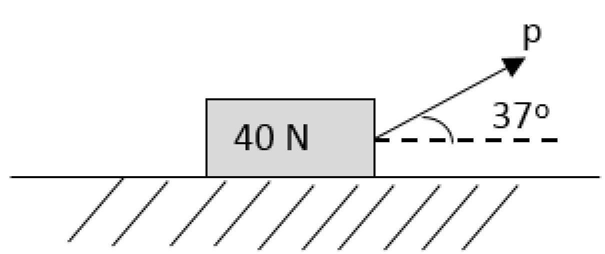
$\mu_s = \frac{F_s}{N} = \tan \emptyset$



EX: For the (40N) horizontal body shown, Find: -

The force acting on the thread which make the body move from rest (motionless) is (μs= 0.5).

The force needed to keep the body moving continuously in a uniform velocity and in a straight line if (μk = 0.2).



Sol:

$\sum F_x = 0$

$p \times \cos 37 - F_s = 0$ ➡ $F_s = p \times \cos 37$ −−−−−−−(1)

$\sum F_y = 0$ ➡ $N + P\, sin\, 37 - 40 = 0$ −−−−−−−−−−(2)

$F_s = \mu_s\, N = 0.5\, N$ −−−−−−−− −−− (3)

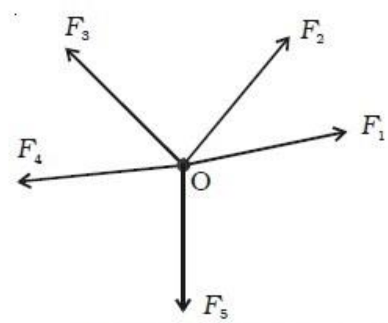
Sub. (3) in (1) 0.8P=0.5N ➡ $N = 1.6\, P$ ➡ Sub. In (2)

$1.6\, P + 0.6\, P = 40$ ➡ 2.2 P=40 ➡ P=18.181818 Newtons

2 - $F_k = \mu_k\, N = 0.2\, N$ Sub. In (1)

0.8 P=0.2 N ➡ N=4P Sub. In (2) ➡ 4P+0.6P=40 4.6P=40

P=8.695 Newtons

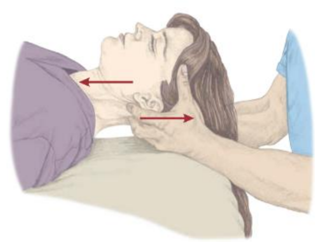


Concurrent force systems

When forces are applied to an object in such a way that their lines of action pass through a single point, they are referred to as concurrent forces.

Parallel forces

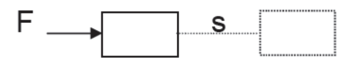
Parallel forces are aligned with each other, but are either adjacent to each other (laterally displaced) or acting at different depths.



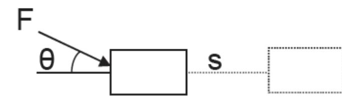
Work

work done by a force is the product of the force and the distance moved in the direction of the force by the point at which it acts.

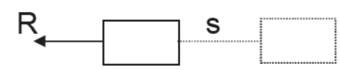
$W = F.S$



$W = F.S. \cos \theta$



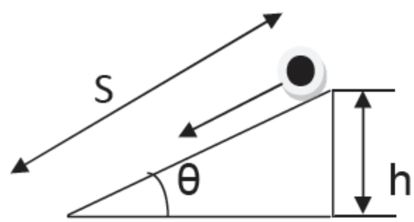
$W = - R. S$



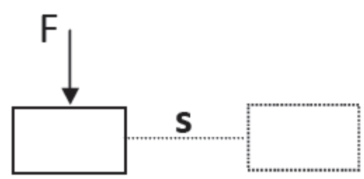
$W= m.g . h$

$W = - m.g . h$

$W= m.g. \sin \theta . s$



$W= 0$

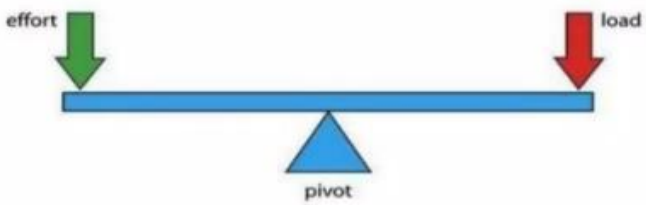


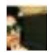
Unit of work: N. m (Joule)

Levers in Human Body (Physiotherapy)

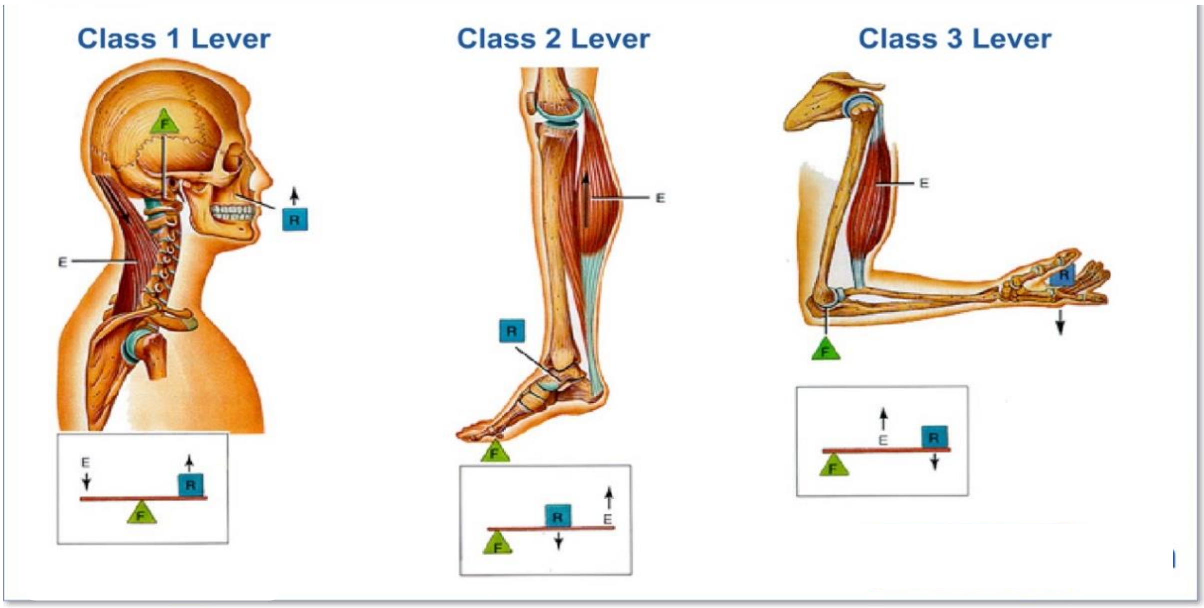
Introduction

A lever is a rigid bar which is capable of movement about a fixed point called a fulcrum (F). work is done when a force or effort (E), applied at one point on the lever, acts upon another force or weight (W), acting at a second point on the lever . the perpendicular distances from the fulcrum to the effort(E) may be called The "effort's arm" and that from the fulcrum to the weight(W) as the "weight's arm".





In the body a lever is represented by a bone, which is capable of movement about a fulcrum formed at the articulating surfaces of a joint; the effort which works the lever is supplied by the force of muscular contraction, applied at the point of insertion to the bone, while the weight may be either at the center of gravity of the part moved, or of the object to be lifted.

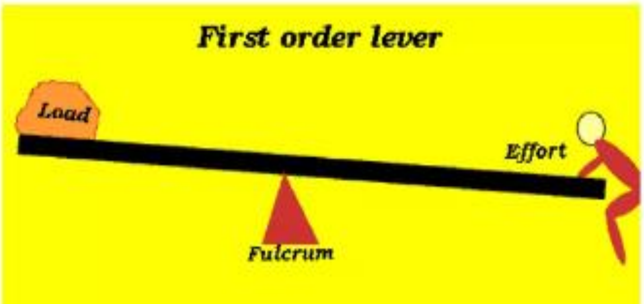


Classifications of Levers

- There are three orders or classed of levers, each of which is characterized by the relative positions of the fulcrum, effort and weight.
- 1st order lever
- 2nd order lever
- 3rd order lever

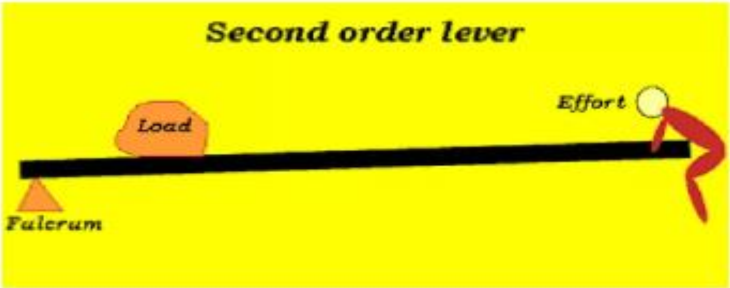
1st Order Lever

- The fulcrum is between the effort and the weight; is may be situated centrally, or towards either the effort or the weight, consequently the effort's and the weight's arms may be equal, or one may exceed the other in length.



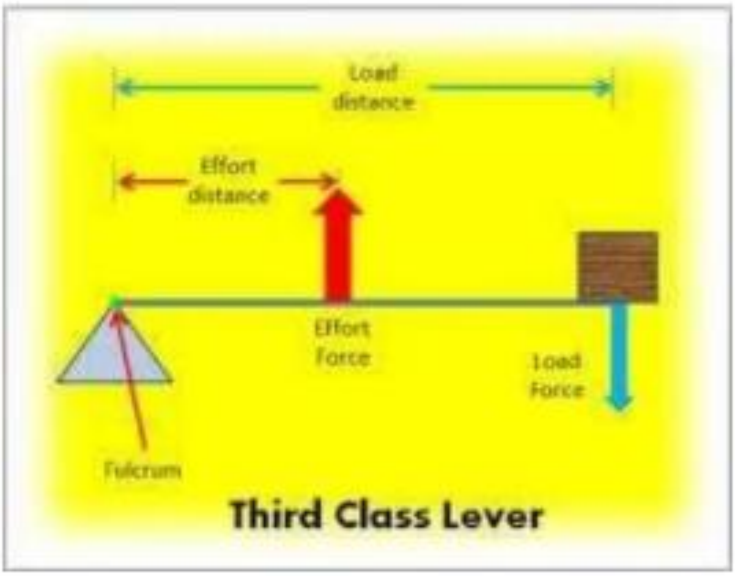
2ND Order Lever

- The weight(load) is between the fulcrum and the effort, and the effort's arm must therefore always exceed the weight' arm.



3rd Order Lever

The effort is between the fulcrum and the weight, and the weight's arm must therefore exceed the effort's arm.



Mechanical Advantage

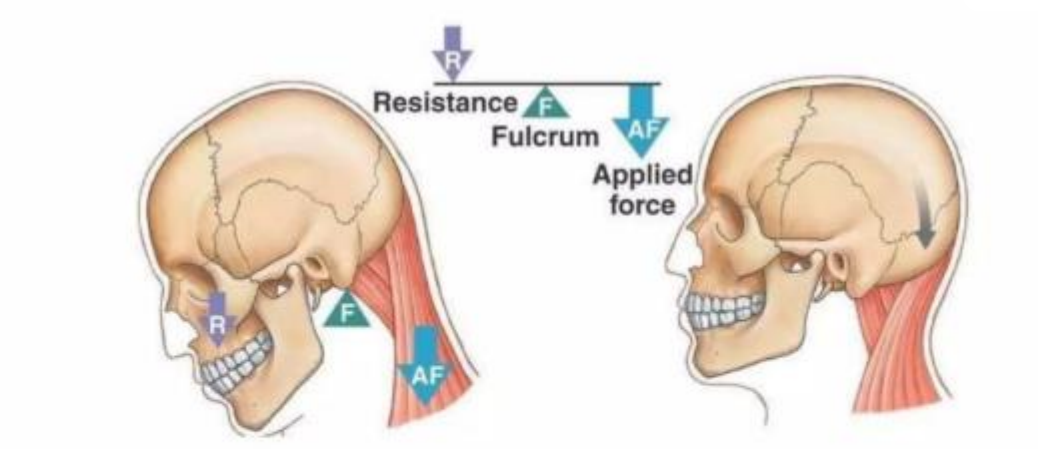
- MECHANICAL ADVANTAGE : the efficacy of a force in relation to a lever is dependent upon tow factors, i.e the force exerted (W) or (E) , and its perpendicular distance from the fulcrum (weight's arm or effort's arm). The product of these two factors is known as the Moment of Force (or toque). When the weight's and effort's arms are of equal length and effort of a magnitude equal to that of the weight will be required to lift it. No advantage is gained but the machine is useful for measuring weights as, for example, in the common balance.

If, however, the length of the effort's arm exceeds that of the weight's arm, less effort will be required to achieve a similar result and an advantages will be gained by the use of the lever. This is known as a Mechanical advantage, and it is obtained in levers of the 1st order when the fulcrum is nearer to the weight than to the effort, and in all levers of the 2nd order. It is never obtained in levers of the 3rd order.

Levers of the Body

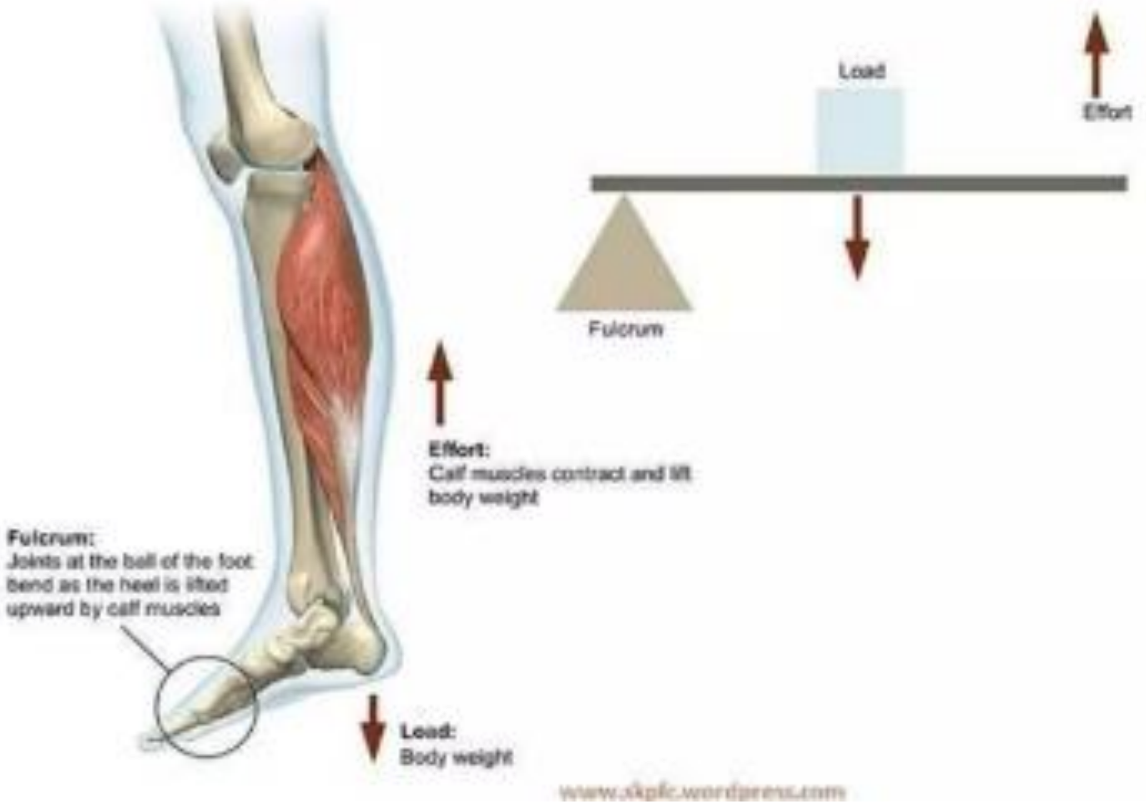
1st order lever

- the feature of this order is stability, and a state of equilibrium can be achieved either with or without mechanical advantage. One example of this type of lever is demonstrated during nodding movement of the head; the skull represents the lever, the atlanto-occipital joints the fulcrum, the weight is situated anteriorly in the face, and the effort is supplied by the contraction of the posterior Neck muscles, applied at their attachment to the occipital bone.



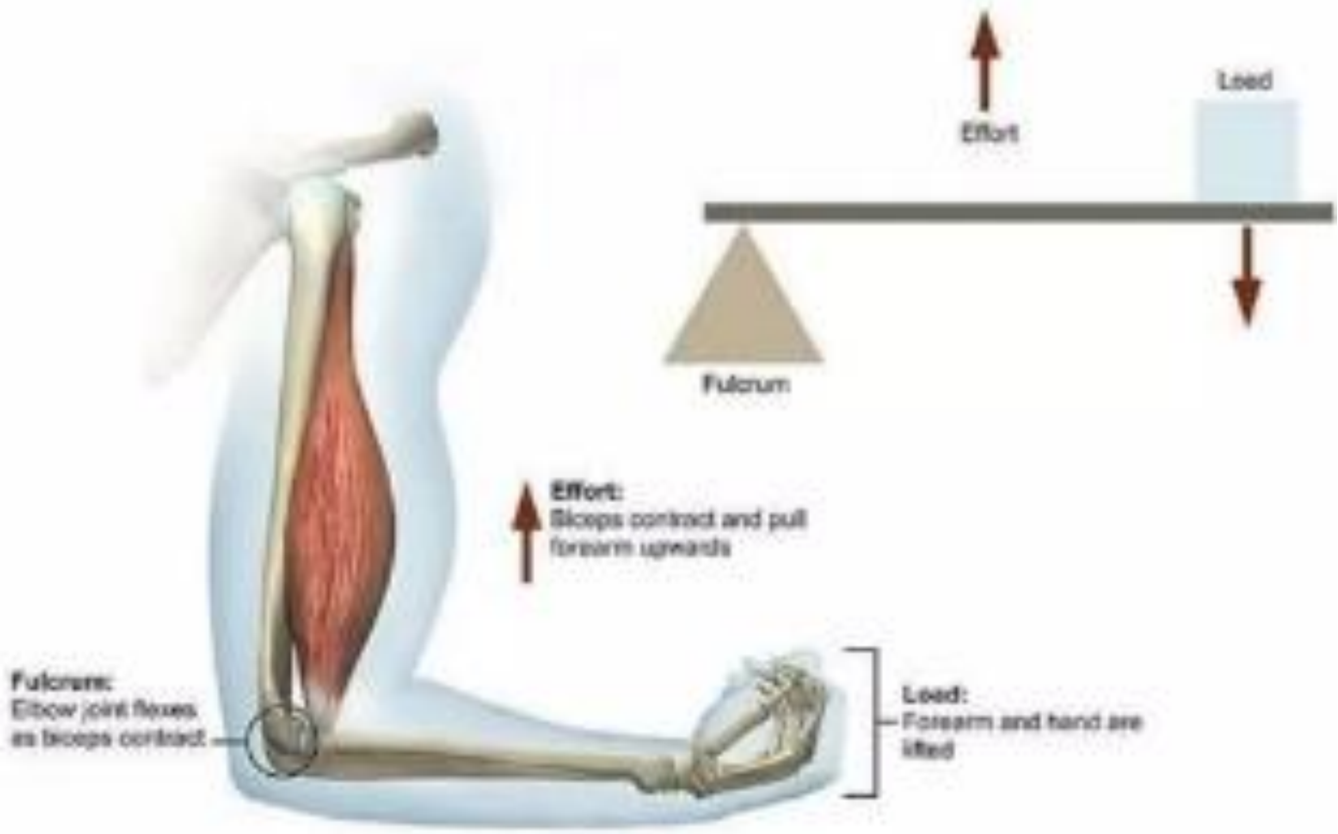
2nd order lever

- this is the lever of power as there must always be a mechanical advantage. An example in the lower limb is demonstrated when the heels are raised to stand on the toes. The tarsal and metatarsal bones are stabilized by muscular action to form the lever, the fulcrum is at the metatarsophalangeal join, and the weight of the body is transmitted through the ankle joint to the talus. The effort is applied at the insertion of the tendo- calcneum by the contraction of the calf muscle.



3rd order lever

- in the human body there are more examples of the 3rd order of levers than of any other types. This type of lever, in which there is always a mechanical disadvantages, is the lever of velocity, the loss of mechanical advantage being outweighed by the advantages gained by speed and range of movement. Both in the days of primitive man and in modern times, speed and range of movement have often proved to be a greater asset than power.


Load
Effort
Fulcrum
Effort:
Biceps contract and pull
forearm upwards
Fulcrum:
Elbow joint flexes
as biceps contract
Load:
Forearm and hand are
lifted

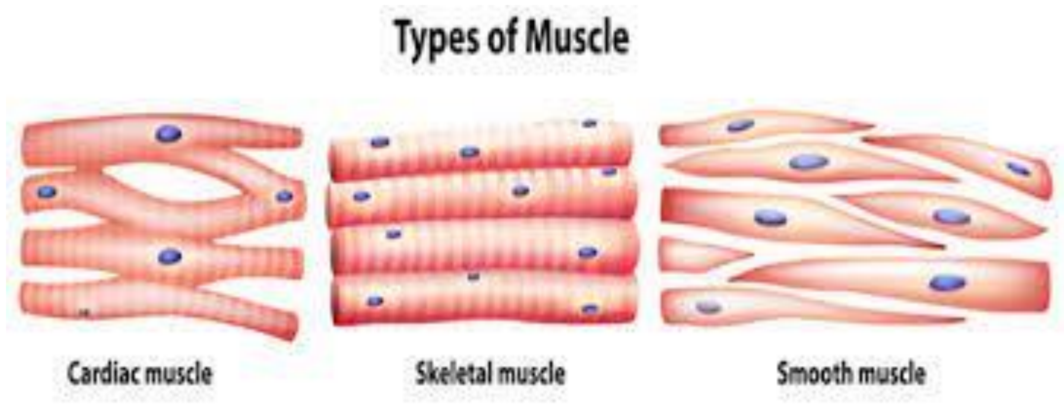
Mobility and stability functions of muscles

The muscular system consists of various types of muscle that each play a crucial role in the function of the body. Muscular system functions include mobility, stability, posture, circulation, and more.

Muscles allow a person to move, speak, and chew. They control heartbeat, breathing, and digestion. Other seemingly unrelated functions, including temperature regulation and vision, also rely on the muscular system.

The muscular system contains more than 600 muscles that work together to enable the full functioning of the body.

The muscle, fascia and elastic connective tissue surrounding a joint function to create movement and provide the stability responsible for controlling joint position while it is in motion. Optimal mobility allows a joint to experience full, unrestricted motion while controlling the constantly moving axis of rotation. Greater stability, flexibility, and mobility ensure that athletes maintain proper exercise techniques and reach their full range of motion in order for target muscles to fire and strength to improve. Mobility and stability are two of the most important factors in recovering from and preventing injury.



There are 3 types of muscles in the body:

Skeletal muscle

Skeletal muscles are the only muscles that can be consciously controlled. They are attached to bones, and contracting the muscles causes movement of those bones.

Any action that a person consciously undertakes involves the use of skeletal muscles. Examples of such activities include running, chewing, and writing.

Smooth muscle

Smooth muscle lines the inside of blood vessels and organs, such as the stomach, and is also known as visceral muscle.

It is the weakest type of muscle but has an essential role in moving food along the digestive tract and maintaining blood circulation through the blood vessels.

Smooth muscle acts involuntarily and cannot be consciously controlled.

Cardiac muscle

Located only in the heart, cardiac muscle pumps blood around the body. Cardiac muscle stimulates its own contractions that form our heartbeat. Signals from the nervous system control the rate of contraction. This type of muscle is strong and acts involuntarily.

Eleven main functions of the muscular system

The main functions of the muscular system are as follows:

1. Mobility

The muscular system's main function is to allow movement. When muscles contract, they contribute to gross and fine movement.

Gross movement refers to large, coordinated motions and includes:

- walking
- running
- swimming

Fine movement involves smaller movements, such as:

- writing
- speaking
- facial expressions

The smaller skeletal muscles are usually responsible for this type of action.

Most muscle movement of the body is under conscious control. However, some movements are reflexive, such as withdrawing a hand from a source of heat.

2. Stability

Muscle tendons stretch over joints and contribute to joint stability. Muscle tendons in the knee joint and the shoulder joint are crucial in stabilization.

The core muscles are those in the abdomen, back, and pelvis, and they also stabilize the body and assist in tasks, such as lifting weights.

3. Posture

Skeletal muscles help keep the body in the correct position when someone is sitting or standing. This is known as posture.

Good posture relies on strong, flexible muscles. Stiff, weak, or tight muscles contribute to poor posture and misalignment of the body.

Long-term, bad posture leads to joint and muscle pain in the shoulders, back, neck, and elsewhere.

4. Circulation

The heart is a muscle that pumps blood throughout the body. The movement of the heart is outside of conscious control, and it contracts automatically when stimulated by electrical signals.

Smooth muscle in the arteries and veins plays a further role in the circulation of blood around the body. These muscles maintain blood pressure and circulation in the event of blood loss or dehydration.

They expand to increase blood flow during times of intense exercise when the body requires more oxygen.

5. Respiration

Breathing involves the use of the diaphragm muscle.

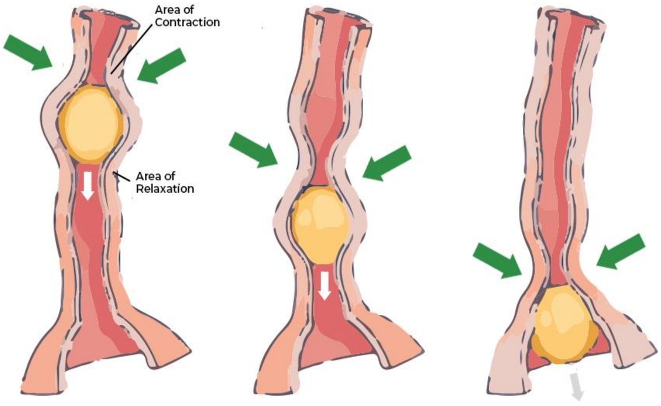
The diaphragm is a dome-shaped muscle located below the lungs. When the diaphragm contracts, it pushes downward, causing the chest cavity to get bigger. The lungs then fill with air. When the diaphragm muscle relaxes, it pushes air out of the lungs.

When someone wants to breath more deeply, it requires help from other muscles, including those in the abdomen, back, and neck.

6. Digestion

Smooth muscles in the gastrointestinal tract control digestion.

Food moves through the digestive system with a wave-like motion called peristalsis. Muscles in the walls of the hollow organs contract and relax to cause this movement, which pushes food through the esophagus into the stomach.



The upper muscle in the stomach relaxes to allow food to enter, while the lower muscles mix food particles with stomach acid and enzymes.

The digested food moves from the stomach to the intestines by peristalsis. From here, more muscles contract to pass the food out of the body.

7. Urination

The urinary system comprises both smooth and skeletal muscles,

The muscles and nerves must work together to hold and release urine from the bladder.

8. Childbirth

Smooth muscles in the uterus expand and contract during childbirth. These movements push the baby. Also, the pelvic floor muscles help to guide the baby’s head down the birth canal.

9. Vision

Six skeletal muscles around the eye control its movements. These muscles work quickly and precisely, and allow the eye to:

- maintain a stable image
- scan the surrounding area
- track moving objects

10. Organ protection

Muscles in the torso protect the internal organs at the front, sides, and back of the body. The bones of the spine and the ribs provide further protection.

Muscles also protect the bones and organs by absorbing shock and reducing friction in the joints.

11. Temperature regulation

Maintaining normal body temperature is an important function of the muscular system. Almost 85 percent of the heat a person generates in their body comes from contracting muscles.

When body heat falls below optimal levels, the skeletal muscles increase their activity to make heat. Shivering is one example of this mechanism. Muscles in the blood vessels also contract to maintain body heat.

Body temperature can be brought back within normal range through the relaxation of smooth muscle in the blood vessels. This action increases blood flow and releases excess heat through the skin.

Five facts about the muscular system

1. Muscles make up approximately 40 percent of total weight.
2. The heart is the hardest-working muscle in the body. It pumps 5 quarts of blood per minute and 2,000 gallons daily.
3. The gluteus maximus is the body's largest muscle. It is in the buttocks and helps humans maintain an upright posture.
4. The ear contains the smallest muscles in the body alongside the smallest bones. These muscles hold the inner ear together and are connected to the eardrum.
5. A muscle called the masseter in the jaw is the strongest muscle by weight. It allows the teeth to close with a force of up to 55 pounds on the incisors or 200 pounds on the molars.

Muscles have several functions in the body:

1- They move the bones of the skeleton.
2- They enable the heart to beat.
3- They can be found in the walls of hollow organs, such as the intestines, uterus and stomach.
4- They allow a person to move, speak, and chew.
5- They control heartbeat, breathing, and digestion.

Effects of immobilization

the process of stopping something or someone from moving or prevent (something or someone) from moving or operating as normal.

Skeletal muscle and immobilization are linked in a dual causal relationship. Muscle paralysis is an obvious cause of immobilization. On the other hand, when muscles are immobilized by extraneous forces they undergo changes which may permanently affect their structure and function.

Immobilizing muscle results almost immediately in a significant loss in muscle mass and volume. The process of muscle wasting is called **muscle atrophy**. The muscle enters a catabolic state losing mass and volume, resulting in a decrease in strength and function.

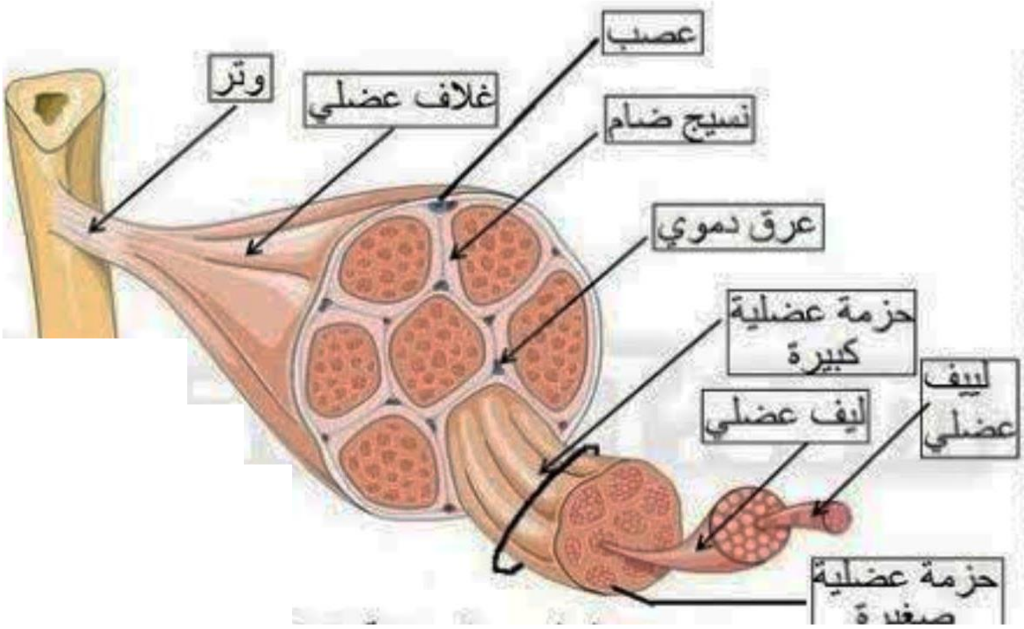
Aging

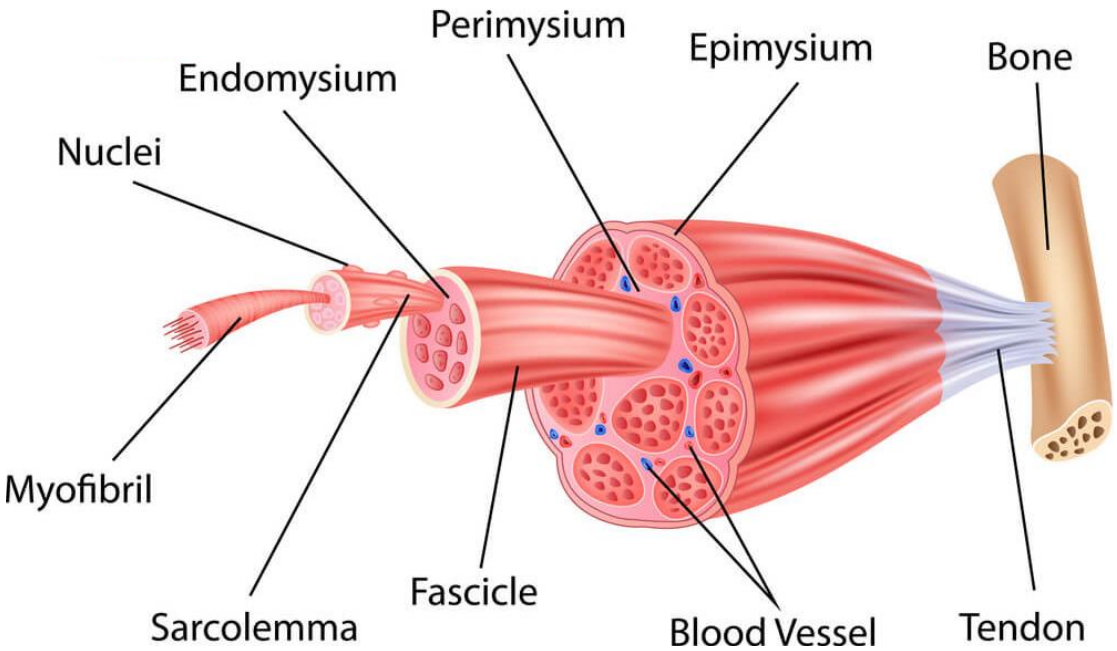
Muscle loses size and strength as we get older, which can contribute to fatigue, weakness and reduced tolerance to exercise. This is caused by a number of factors working in combination, including: Muscle fibers reduce in number and shrink in size.

Elements of muscle structure

A **muscle** is made up of fibers of muscle cells surrounded by protective tissue, bundled together with many more fibers, all surrounded by a thick protective tissue. There are several types of **muscle** that act on various parts of the body. Skeletal muscles, which are the organs of the skeletal **muscle** system, include three layers of connective tissue that enclose and provide structure to the **muscle** as a whole. The outer layer of each **muscle** fiber is wrapped with a layer of connective tissue called the epimysium. The epimysium allows muscle to contract and move powerfully while maintaining its structural integrity. It also separates muscle from other tissues and organs

[(17) تركيب العضلات الهيكلية المخططة - YouTube]





Gait Analysis

The Normal Gait Cycle

Everyone has a slightly different way of walking, but in general these ways are similar enough to be called “normal” gait. We need to understand the normal way before we can recognize what is abnormal.

We cannot align or fit a prosthesis or orthosis unless we understand exactly what is normal.

One gait cycle is measured from heel strike to heel strike once more on the same leg.

The gait cycle can be divided into two phases.

1- **Stance Phase**

- Period of time that the foot is on the ground.

-Approximately 60% of one gait cycle is spent in stance.

-During stance, the leg accepts body weight and provides single limb support.

2- **Swing Phase**

- Period of time that the foot is off the ground moving forward.

- Approximately 40% of one gait cycle is spent in swing.

-The limb advances.

In turn, the stance phase and swing phase are divided into more specific phases in classic gait terms and new gait terms as follow :(show figures)

In classic gait terms:

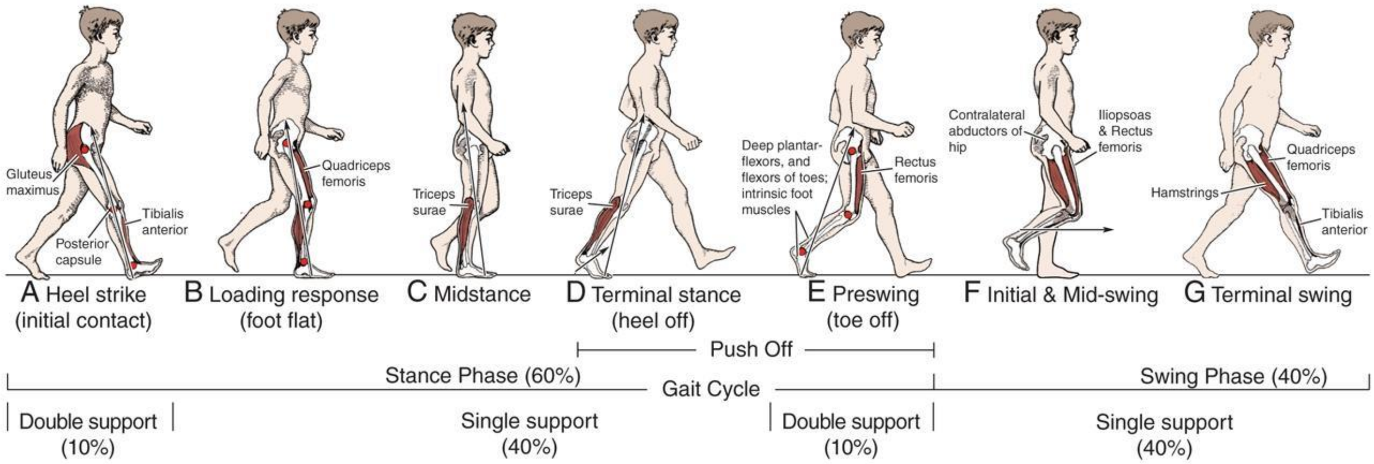
Stance Phase: (1- Heel strike 2- foot flat 3- midstance 4-heel off 5-toe off)

Swing Phase: (1-Acceleration 2-Mid-swing 3-Deceleration)

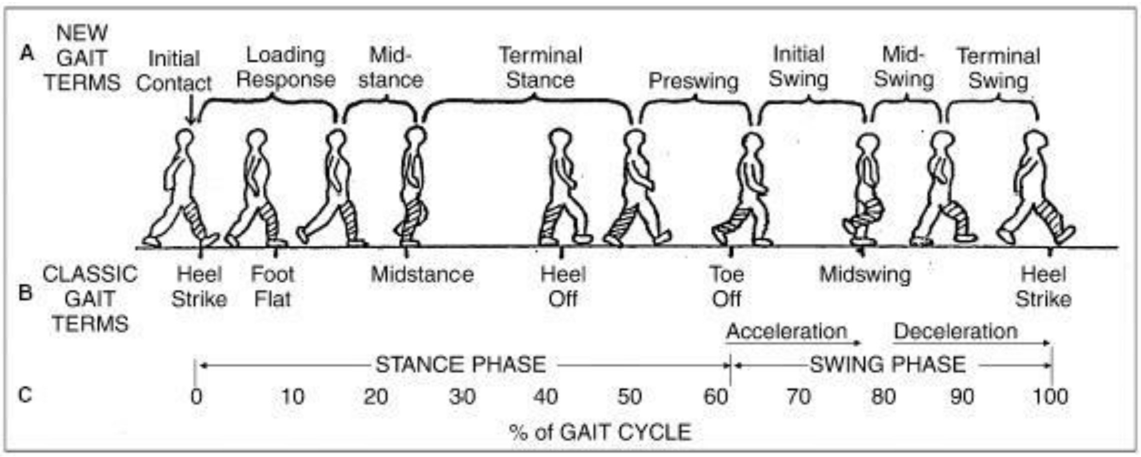
Whereas, **in new gait terms:**

Stance Phase: (1- initial contact 2- loading response 3- midstance 4- terminal stance 5- preswing).

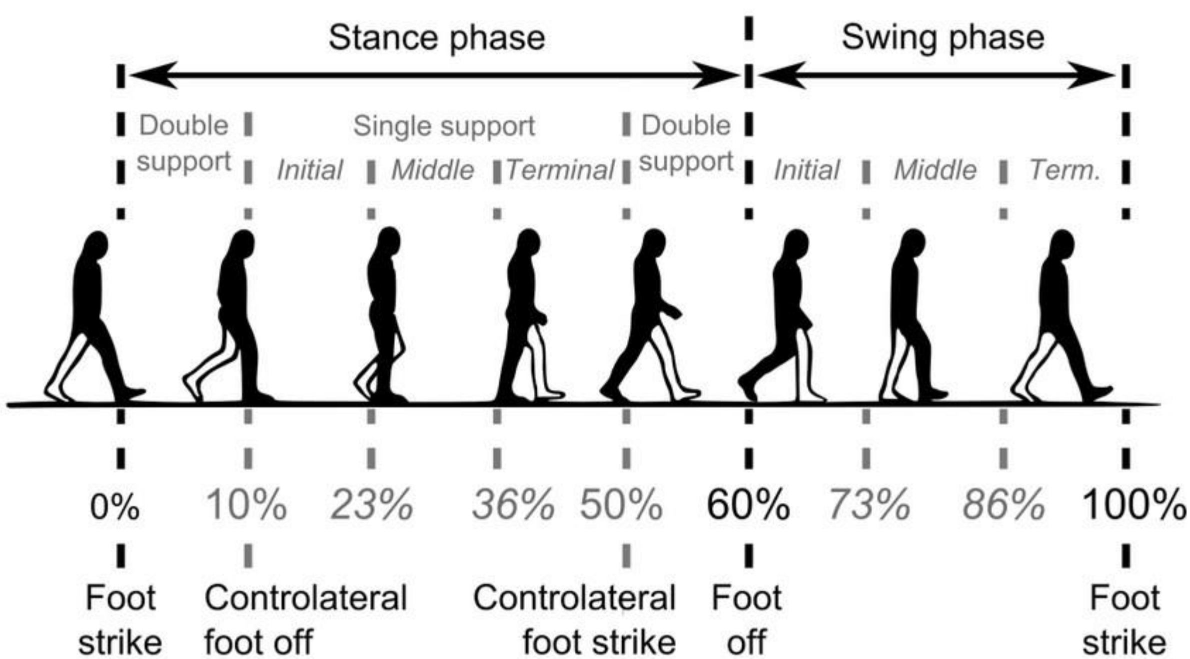
Swing Phase: (1- initial swing 2- Mid- swing 3- Terminal swing)



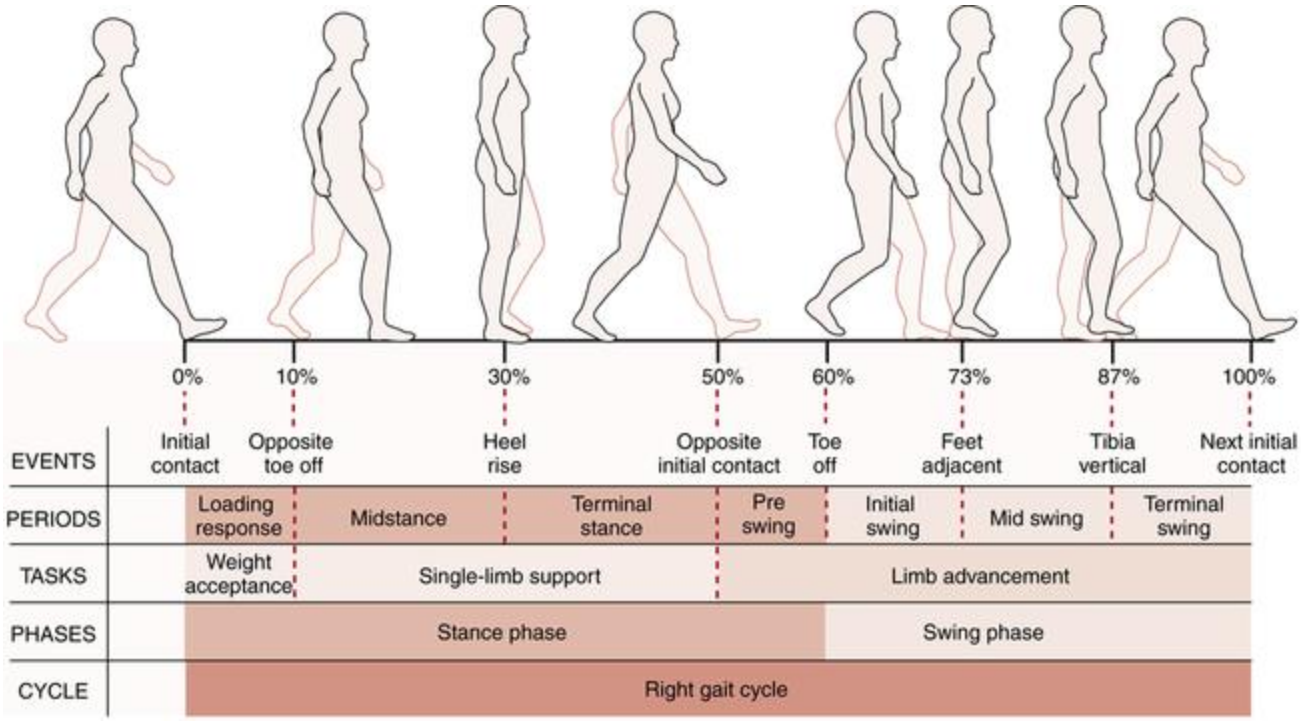
Gluteus maximus
Posterior capsule
Tibialis anterior
Quadriceps femoris
Triceps surae
Triceps surae
Deep plantar-flexors, and flexors of toes; intrinsic foot muscles
Rectus femoris
Contralateral abductors of hip
Iliopsoas & Rectus femoris
Hamstrings
Quadriceps femoris
Tibialis anterior
A Heel strike (initial contact)
B Loading response (foot flat)
C Midstance
D Terminal stance (heel off)
E Preswing (toe off)
F Initial & Mid-swing
G Terminal swing
Push Off
Stance Phase (60%)
Gait Cycle
Swing Phase (40%)
Double support (10%)
Single support (40%)
Double support (10%)
Single support (40%)



A
NEW GAIT TERMS
Initial Contact
Loading Response
Mid-stance
Terminal Stance
Preswing
Initial Swing
Mid-Swing
Terminal Swing
B
CLASSIC GAIT TERMS
Heel Strike
Foot Flat
Midstance
Heel Off
Toe Off
Midswing
Heel Strike
Acceleration
Deceleration
STANCE PHASE
SWING PHASE
C
0 10 20 30 40 50 60 70 80 90 100
% of GAIT CYCLE



Stance phase
Swing phase
Double support
Single support
Double support
Initial
Middle
Terminal
Initial
Middle
Term.
0%
10%
23%
36%
50%
60%
73%
86%
100%
Foot strike
Controlateral foot off
Controlateral foot strike
Foot off
Foot strike



CLASSIC GAIT TERMINOLOGY:	Heel Strike	Foot Flat	Midstance	Heel Off	Toe-Off	Acceleration	Midswing	Deceleration
Rancho Los Amigos Terms NEW TERMINOLOGY	INITIAL CONTACT	LOADING RESPONSE	MID STANCE	TERMINAL STANCE	PRE-SWING	INITIAL SWING	MID SWING	TERMINAL SWING
	STANCE PHASE 60%					SWING PHASE 40%		
% OF TOTAL PHASE	0-2%	0-10%	10-30%	30-50%	50-60%	60-73%	73-87%	87-100%
ILIOPSOAS	inactive	inactive	inactive	concentric	concentric	concentric	concentric	inactive
GLUTEUS MAXIMUS	eccentric	inactive	inactive	inactive	inactive	inactive	inactive	inactive
GLUTEUS MEDIUS	eccentric	eccentric	eccentric	eccentric	inactive	inactive	inactive	inactive
HAMSTRINGS	eccentric	eccentric	inactive	inactive	inactive	eccentric	eccentric	eccentric
QUADRICEPS	eccentric	eccentric	inactive	inactive	eccentric	eccentric	inactive	inactive
PRETIBIAL MUSCLES	eccentric	eccentric	inactive	inactive	inactive	concentric	concentric	concentric
CALF MUSCLES	inactive	inactive	eccentric	concentric	concentric	inactive	inactive	inactive

KEY:

INACTIVE	CONCENTRIC	ECCENTRIC

Strength of Materials

Strength of materials: is the science which deals with relations between externally applied loads and their internal effects on bodies.

Stress:

Is the force of resistance offered a body against the deformation.

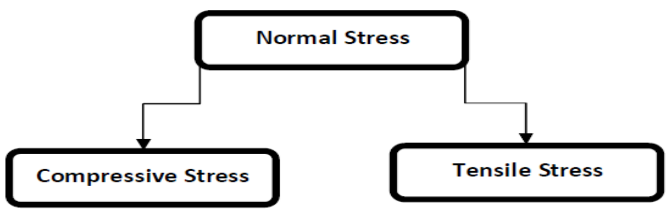
$$Stress = \frac{P}{A}$$

Where:

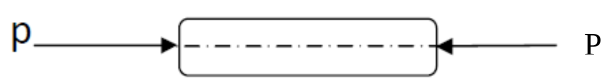
P: applied load   A: cross-sectional area

There are two types of stress :-

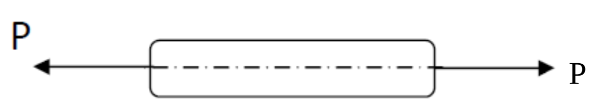
1- **Normal Stresses:** when the force acts perpendicular to the cross-section area



A) Compression (compressive stress) σ_c



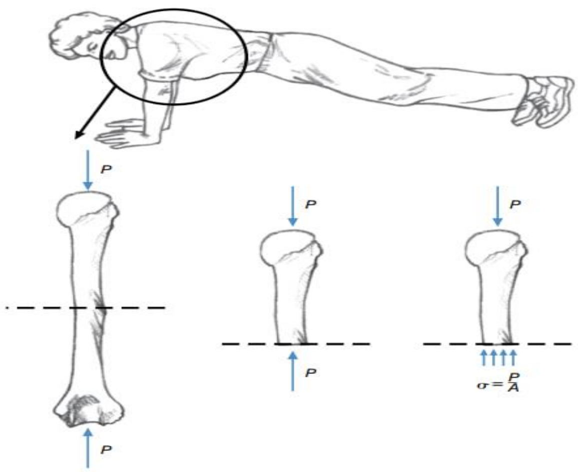
B) Tension stress (σ_t):

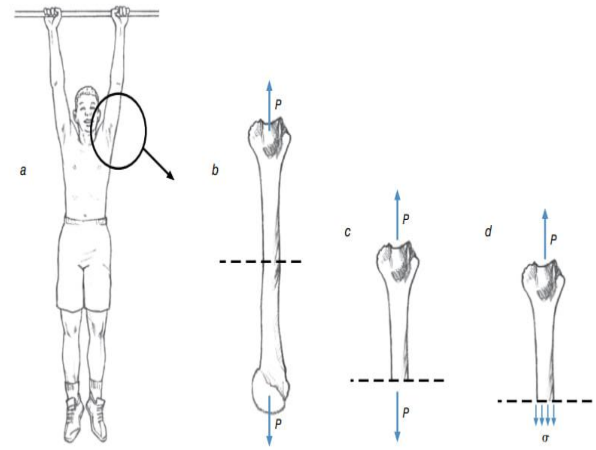


2-Shearing (Tangential) stress (τ): The stress which is caused by force acting a long or parallel to the area resisting the forces sometimes called tangential tress.

$$\tau = \frac{P}{A}$$

Where: P = shearing force   A = area being sheared a long or parallel to p





Strain (ϵ):

Is the deformation accompany loading.

Or

Is the change in shape or size produced in unit dimension of a body subjected to an external force.

$$\epsilon = \frac{\delta}{L_o} = \frac{L - L_o}{L_o}$$

δ : the elongation(الاستطالة)

L_o : origin length, L: finally length

Elasticity, ability of a deformed material body to return to its original shape and size when the forces causing the deformation are removed.

Plasticity: the limit in which the material will not return to its original shape when unload.

Notes:

1-Normal stress (axial load) ⟹ normal strain (elongation).

2-Strain is a dimensionless quantity.

3- Units of stress are:

[N / m^2 (Pascal) (pa), N / mm^2 , Ib / ft^2 , Ib / in^2 (psi)]

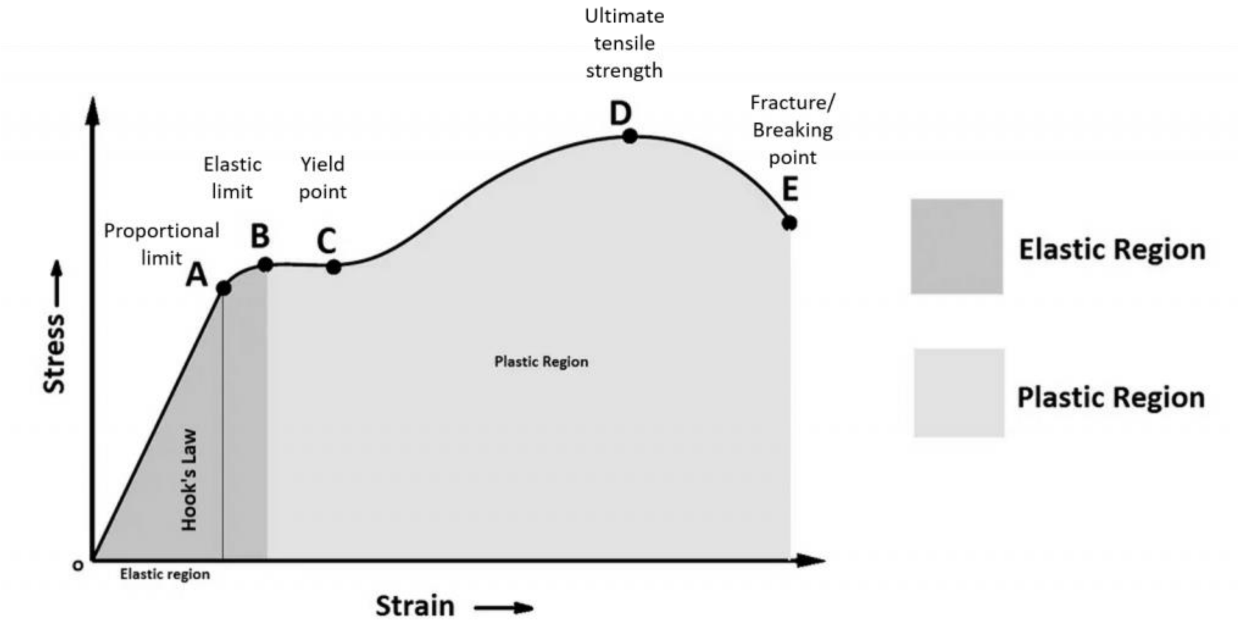
[10^6 N / m^2 = 10^6 pa = 1 MPa , 10^9 Pa = G Pa]

Hooke's law

Hooke's law describes the elastic properties of materials only in the range in which the force and displacement are proportional.

$$E = \frac{\sigma}{\epsilon} \qquad \sigma = \frac{P}{A} \qquad \epsilon = \frac{\delta}{L}$$

$$E = \frac{\frac{P}{A}}{\frac{\delta}{L}} = \frac{PL}{A\delta} \qquad \delta = \frac{PL}{AE}$$



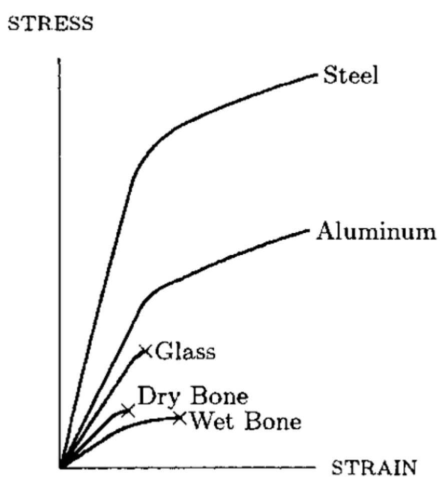


Table *Average mechanical properties of selected materials*

Material	Yield strength σ_Y(MPa)	Ultimate strength σ_U (MPa)	Elastic modulus E (MPa)	Shear modulus GPa	Poisson's ratio V
Muscle	–	0.2	–	–	0.49
Tendon	–	70	0.4	–	0.40
Skin	–	8	0.5	–	0.49
Cortical bone	80	130	17	3.3	0.40
Glass	35–70	–	70–80	–	–
Cast iron	40–260	140–380	100–190	42–90	0.29
Aluminum	60–220	90–390	70	28	0.33
Steel	200–700	400–850	200	80	0.30
Titanium	400–800	500–900	100	45	0.34

Example

If the allowable stress is $\sigma_t = 157 \frac{MN}{m^2}$. for the plate shown find the force F if the diameter of hole is d= 20 mm, the plate's thickness is t= 10 mm and the plate's width is 200 mm?

Answer: –

$A_1 = 0.2 * 0.01 = 0.002\, m^2$

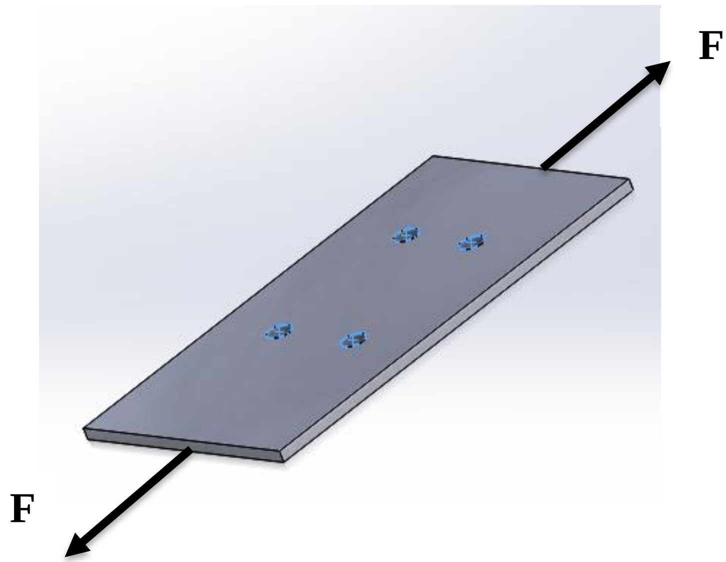
$A_2 = 0.02 * 0.01 * 2 = 0.0004\, m^2$

$\therefore\ 0.002 - 0.0004 = 0.0016\, m^2$

$\sigma_t = \frac{F}{A}$ $\qquad F = \sigma_t * A$

$= 157 * 10^6 * 16 * 10^{-4}$

$\therefore\ F = 251.2\ KN$



Example:

Find the minimum diameter of steel wire when the load exerted on it is 5KN and the stress is not exceed 100 MN/m^2?

Sol.

$\sigma = \frac{P}{A}$ $\qquad P = 5 \times 10^3\ N$ $\qquad \sigma = 100 \times 10^6\, N/m^2$

$$100 \times 10^6 = \frac{5 \times 10^3}{\frac{\pi}{4} d^2}$$

$d = 7.98\ mm$

A sample of biological material is loaded into a material-testing machine. The material is 2 cm long in its unloaded state. A 6000 N tensile force is applied to the material, and it stretches to a length of 2.0004 cm as a result of this force. What is the strain in the specimen when it is stretched this much?

Solution:

Step 1: Identify the known quantities.

$\ell = 2.0004$ cm

$\ell_o = 2.0$ cm

Step 2: Identify the unknown variable to solve for.

$\varepsilon = ?$

Step 3: Search for an equation with the known and unknown variables.

$$\varepsilon = \frac{\ell - \ell_o}{\ell_o}$$

Step 4: Substitute the known quantities and solve for the unknown variable.

$$\varepsilon = \frac{\ell - \ell_o}{\ell_o} = \frac{2.0004 - 2.000}{2.000}$$

$\varepsilon = 0.0002 = 0.02\%$