FORCE ON AND IN THE BODY

Let us now consider the effect on the muscle force needed as the arm changes it angle as shown in (figure *6a). Figure 6b* shows the forces we must consider for an arbitrary angle (α). If we take the torques about the joint we find that M remains constant as α changes.

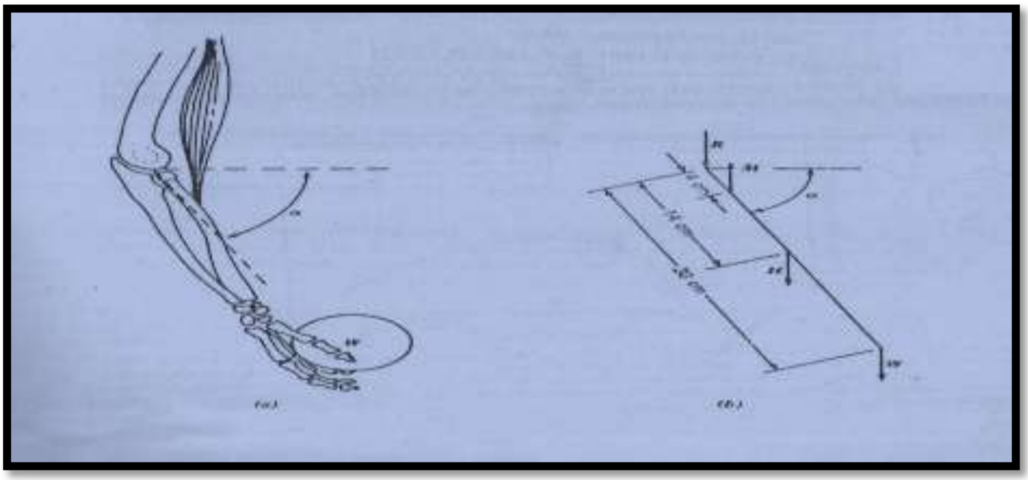


Figure6. The forearm at an angle α to the horizontal. (a) The muscle and bone system. (b) the force and dimensions.

However, the length of the biceps muscle changes with the angle. In general, each muscle has a minimum length to which it can be contracted and a maximum length to which it can be stretched and still function. At these two extremes the force the muscle can exert is essentially zero. At some point in between, the muscle can produce its maximum force (*figure 7*).

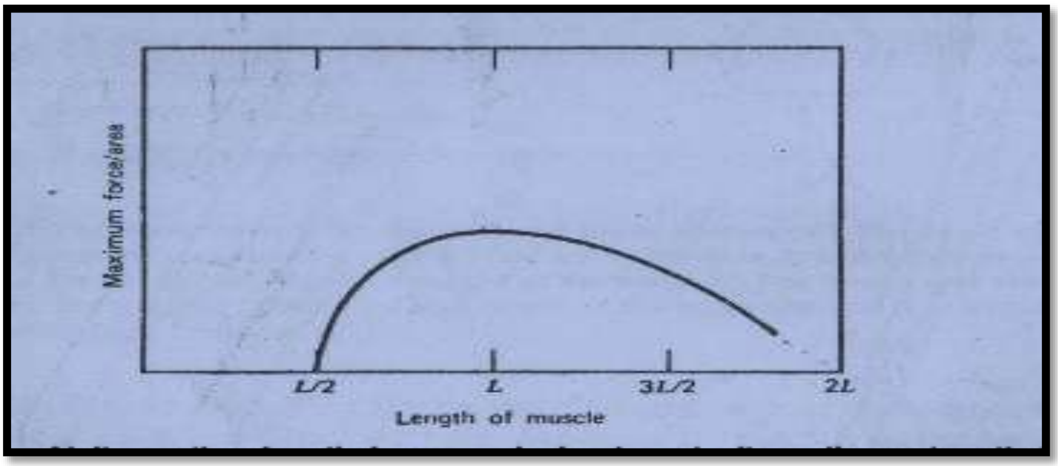


Figure7. At its resting length L a muscle is close to its optimum length for production force. At about half this length it cannot shorten further and the force it can produce drops to (0), whereas at a stretch of about 2L irreversible tearing of the muscle takes place.

If the biceps pulls vertically the angle of the forearm does not affect the force required **but** it does affect the length of the biceps muscle, which affects the ability of the muscle to provide the needed force.

The arm can be raised and held out horizontally from the shoulder by the deltoid muscle(*figure8 a*); we can show the forces schematically (*figure 8* b).By taking the sum of the torques about the shoulder joint ,the tension T can be calculate from

$$\mathbf{T} = \frac{2W1 + 4W2}{sin\alpha}$$

W_1(the weight of the arm),and W_2(the weight in the hand).

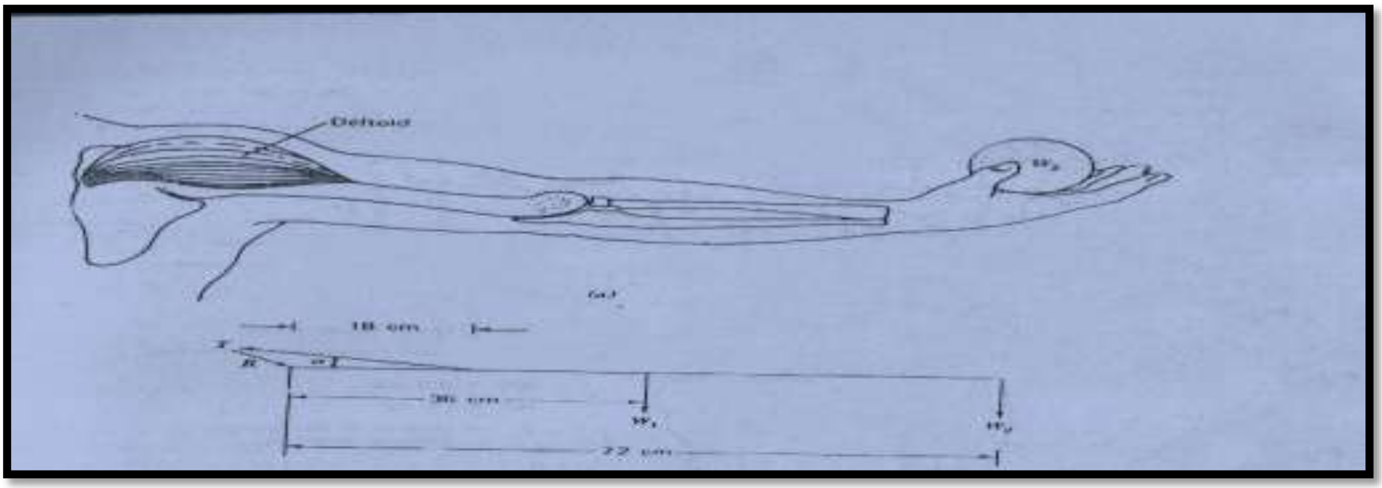


Figure 8. Raising the arm.(a) The deltoid muscle and bone structure involved.(b)The forces on the arm. T is the tension in The deltoid muscle fixed at the angle α, R is the reaction force on the shoulder joint,W_1 is the weight of the arm located at its center of gravity, and W_2 is the weight in the hand.

Example 3: As a show in above figure where: W1 (the weight of the arm) = 68N, and W2 (the weight in the hand)=100N. If $\alpha = 16°$ find the (T) the tension in the deltoid muscle?

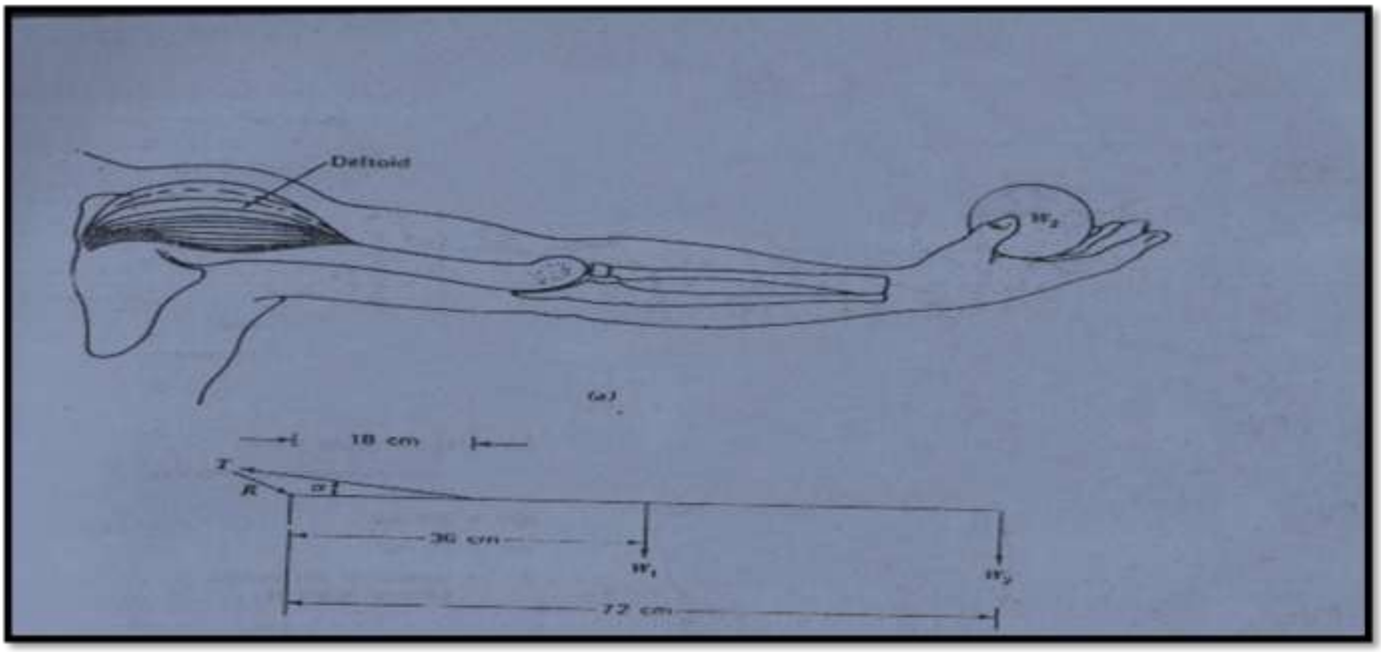
$$\mathbf{T} = \frac{2W1 + 4W2}{sin\alpha}$$

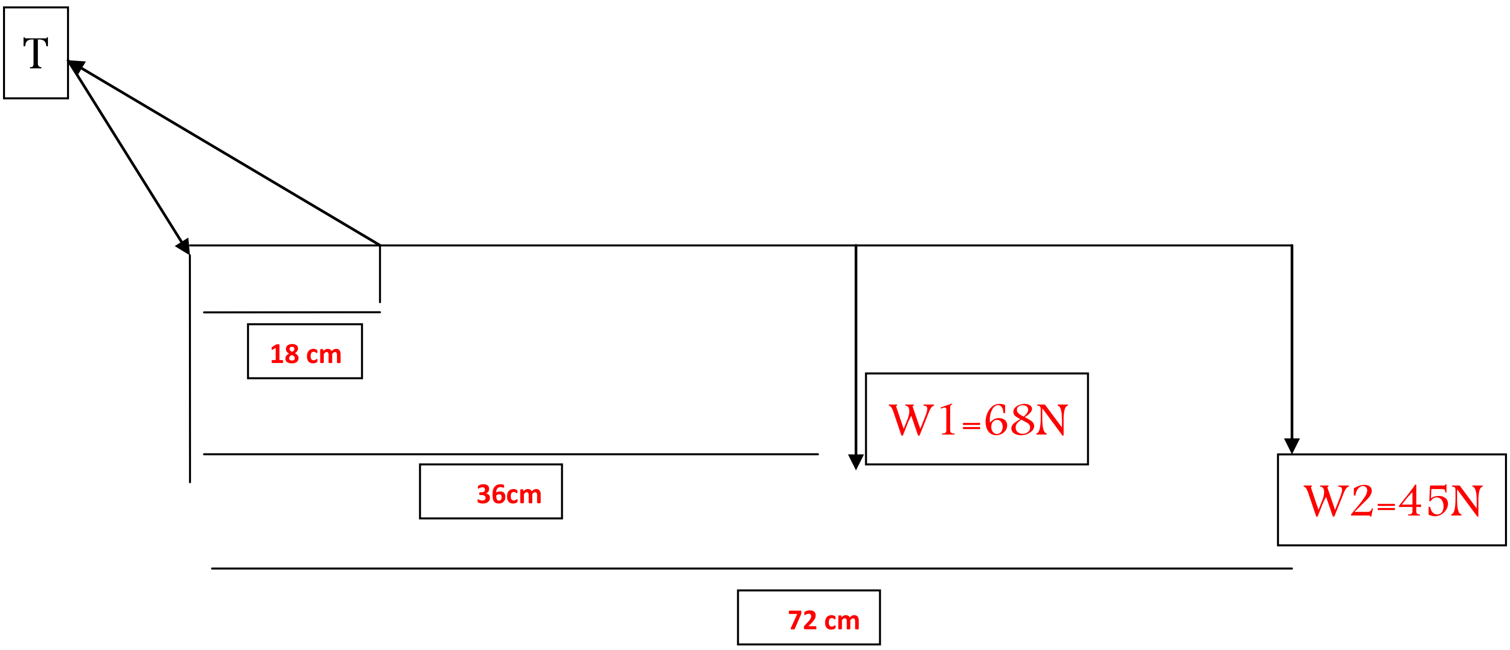
$$\mathbf{T} = \frac{2(68) + 4(100)}{sin16}$$

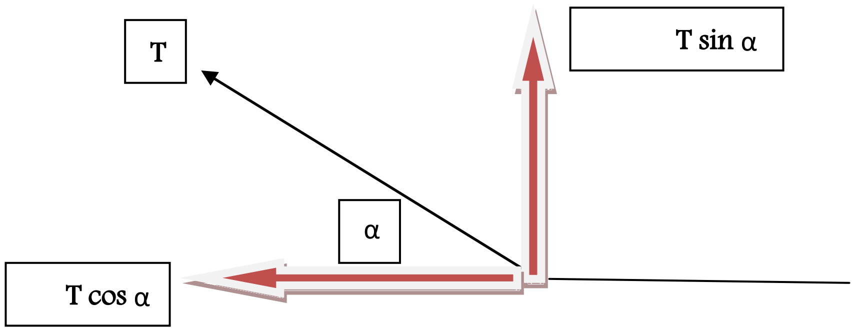
T=1944 N.

The force needed to hold up the arm is surprisingly large

Example 4: As below figure, what is the force needed to held up the arm under the state of raising the arm (α=16°, W1= 68N, W2=45N)?







Sol-:. T at angle α resolved into two components.(T sin α) , (T cos α)and taking the sum of the torques about the shoulder joint.

$$\sum \tau = 0$$

$$-(68 \times 36 \times 10^{-2}) + \{-(45 \times 72 \times 10^{-2})\} + T \sin\alpha \times (18 \times 10^{-2}) = 0$$

T=1145N the force needed to hold up the arm is large.

2-Dynamic : The force on the body under the constant acceleration or deceleration of one dimensional motion. Also it important when the body is moving and hitting another body.

From the Newton's second law, force equal mass times acceleration, can be written as:-

F=ma

Where: F= the force (N, dyne),

m= the mass (Kg, g),

a= acceleration (cm /sec^2 or m/ sec^2)

Also F = the change of momentum (p) over a short interval of time (t).

$$F = \frac{\Delta P}{t}$$

ΔP = change of momentum = Δ (mv) ,

m=mass, v= velocity of this mass. Δt = interval of time

$$\boldsymbol{F} = \frac{\Delta(\boldsymbol{mv})}{\Delta \boldsymbol{t}}$$

Example 5: A(60 kg) person walking at(1 m/sec)bumps into a wall and stops in a distance of(2.5 cm)in a about(0.05sec) .what is the force developed on impact?

$\Delta(mv)$ = (60 kg)(1m/sec) – (60 kg)(0 m/sec) = 60 kg m/sec

$$\boldsymbol{F} = \frac{\Delta(\boldsymbol{mv})}{\Delta \boldsymbol{t}} = \frac{60 \text{ kg m/sec}}{0.05 \text{ sec}} = 1200\ kg\ m/\ \sec^2 \qquad \text{or} \qquad 1200 \text{ N}$$

Example 6: a-A person walking at (1 m/sec) hits his head on a steel beam. Assume his head stops in (0.5 cm) in about 0.01 sec. If the mass of his head is (4kg), what is the force developed on impact?

$\Delta(mv)$ = (4 kg)(1m/sec) – (4 kg)(0 m/sec) = 4 kg m/sec

$$\boldsymbol{F} = \frac{\Delta(\boldsymbol{mv})}{\Delta \boldsymbol{t}} = \frac{4 \text{ kg m/sec}}{0.01 \text{ sec}} = 400\, kg\, m/\sec^2 \qquad \text{or} \qquad 400 \text{ N}$$

b- If the steel beam has (2cm) of padding and Δt is increased to (0.04 sec), what is the force developed on impact?

$$\boldsymbol{F} = \frac{\Delta(\boldsymbol{mv})}{\Delta \boldsymbol{t}} = \frac{4 \text{ kg m/sec}}{0.04 \text{ sec}} = 100\, kg\, m/\sec^2 \qquad \text{or} \qquad 100 \text{ N}$$

As example of a dynamic force in the body, is the apparent increase of weight when the heart beats (systole).

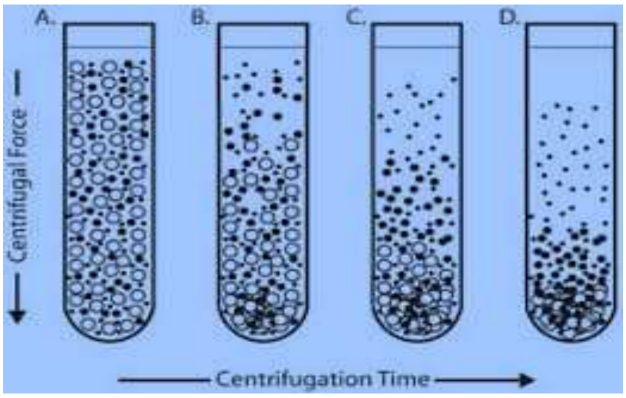
Example 7: (60 gm)of blood is given upward of about(0.1sec) in a velocity nearly (1m/sec), what is the force?

$$\boldsymbol{F} = \frac{\Delta(\boldsymbol{mv})}{\Delta \boldsymbol{t}}$$

$$(60 \times 10^{-3} \times 1)/0.1 = 0.6 \text{ N}$$

The upward momentum given to the mass of blood is $(60 \times 10^{-3} \times 1)$; thus the downward reaction force (Newton's third law) produced on the rest of the body is (0.6 N). This is enough to produce a noticeable jiggle on sensitive spring- type scale

The centrifuge way



The centrifuge way

Is way to increase apparent weight, it is especially useful for separating in a liquid, the centrifuge works using the sedimentation principle. It speeds up the sedimentation that occurs at a slow rate under the force of gravity. In a laboratory centrifuge that uses sample tubes, the radial acceleration causes denser particles to settle to the bottom of the tube, while low density substances rise to the top.

Stock law

Let us consider sedimentation of small spherical objects of density (ρ) in a solution of density (ρ_o) in a gravitational field (g). We know that falling objects reach a maximum terminal velocity due to viscosity effects. Stock has shown that for a spherical object of radius(a), the retarding force (F_d)and terminal velocity (v) are related by :-

$$F_d = 6\pi a v \eta \text{..................stock law}$$

Where:- F_d = retarding force. v = terminal velocity. a = object radius.

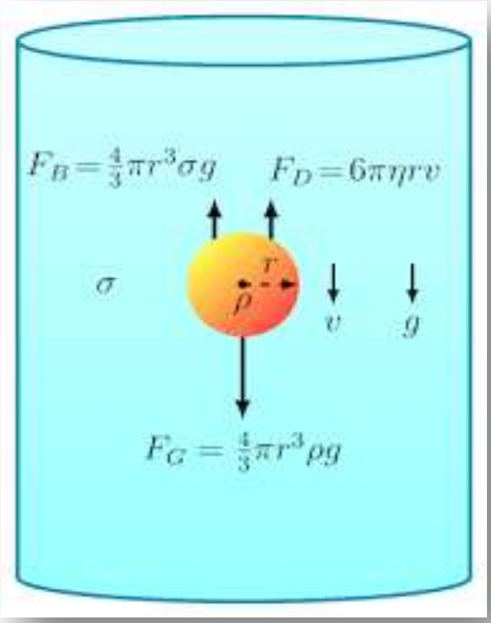
η = the viscosity of the liquid through which the sphere is passing .The SI unit for viscosity is the Pascal second (Pas), The cgs unit for viscosity is the poise (1Pas= 10 poise).

When the particle is moving at a constant speed, the retarding force(F_d) is in equilibrium with the difference between the downward gravitational force(F_g)and the upward buoyant force(F_B) (the weight of the liquid the particle displaces). Thus we have:

- The force of the gravity ⟹ $F_g = 4/3\, \pi\, a^3\, \rho\, g$
- The buoyant force ⟹ $F_B = 4/3\, \pi\, a^3\, \rho_o\, g$
- The retarding force ⟹ $F_d = 6\pi a v \eta$

F_g acts downward and F_B acts upward, and the difference is equal to F_d

$$F_d = F_g - F_B$$



We obtain the expression for the terminal velocity (sedimentation velocity),

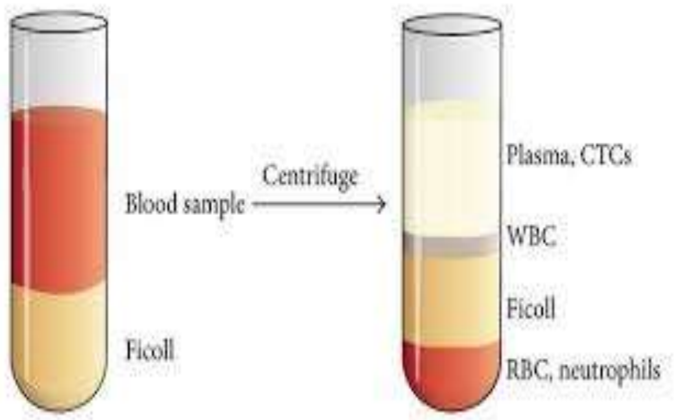
$$v = \frac{2a^2}{9\eta} g(p - p_o)$$

ρ **=** is the density of particles.

ρ_o **or (σ)=** is the density of fluid.

In some forms of disease such as rheumatic fever, rheumatic heart disease, and gout, the red blood cells clump together and the effective radius increases; thus an increased sedimentation velocity occurs. In other diseases such as hemolytic jaundice and sickle cell anemia, the red blood cells change shape or break. The radius decrease; thus the rate of sedimentation of these cells is slower than normal.

Hematocrit (packed cell volume PCV) is the percent of red blood cells in the blood.



Since the sedimentation velocity is proportional to the gravitational acceleration, it can be greatly enhanced if the acceleration is increased. We can increase **g** by means of a centrifuge, which provides an effective acceleration g_{eff}.

$$g_{eff} = 4\pi^2 f^2 r$$

Where (f)is the rotation rate in revolution per second and (r) is the position on the radius of the centrifuge where the solution is located.

Hematocrit depends upon:

- Radius of centrifuge.
- Speed of centrifuge
- Duration of centrifuge.

- A normal hematocrit is 40 – 60.
- a lower value than 40 indicates anemia .
- a high value than 60 indicates poly cythemia.

Polycthmia ⇒ (high number of RBCs in the blood)