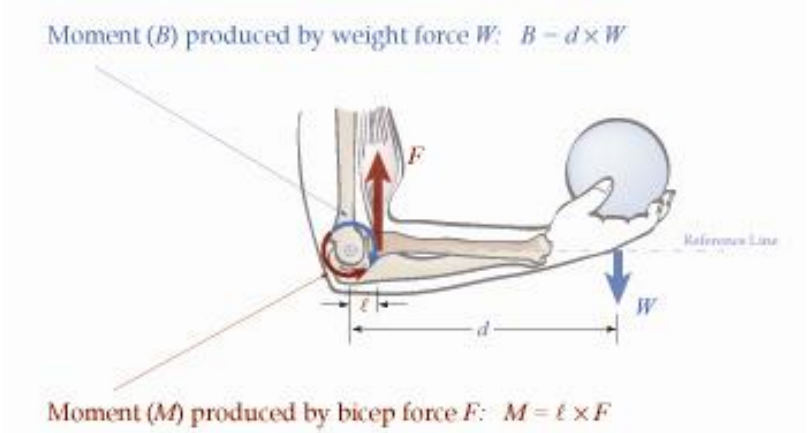
Mechanics of Muscle Motion

One of the fundamental principles in mechanics is the concept of torque. Torque is a twisting effort applied to an object that tends to make the object turn about its axis of rotation. This twisting force, also known as a ***moment*** to engineers, is produced when a force is applied to an object away from the axis or joint. For example, when we apply a force at the handle of a door, it rotates about its hinges and opens. This is similar to our muscles, which contract and produce force acting on our bones in order to rotate our body parts about a joint.

A ***moment*** is the ***product*** of a ***force*** and the perpendicular ***distance*** to its turning axis. For an object to remain in equilibrium (no angular motion), the moments about the axis must be equal. Engineers use a ***free body diagram***, as shown below, to illustrate how the ball and the bicep muscle produce forces that tend to rotate the forearm about the elbow joint. These forces produce moments about the joint that can be written mathematically to describe the motion of the arm.



The moment (M) produced by the bicep muscle must be equal to the moment (B) produced by the ball. *Note: For simplicity, we assume that forces act perpendicular to the reference line and the weight of the arm is negligible.*

Moment produced by bicep muscle $M = \ell F$

Moment produced by weight of ball $B = dW$

these moments must be equal

$$\ell F = dW$$

to find the force required of the bicep to balance the weight, divide both sides by ℓ to get

$$F = \frac{dW}{\ell} \quad \text{or} \quad F = \left(\frac{d}{\ell}\right)W$$

Example: If a typical middle school student ($d = 0.25\ m$, $\ell = 0.0325\ m$) holds a 15 *lb.* bowling ball, the bicep must produce a force of 115 *lbs.* to balance the arm.