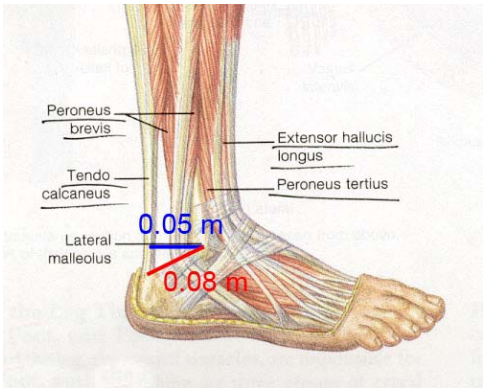
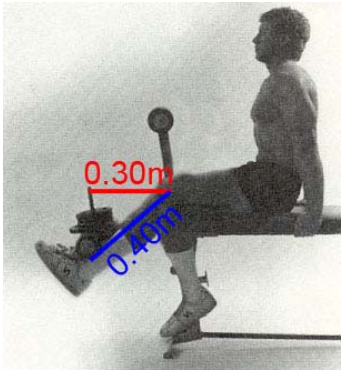
Chapter 6: Torques and Center of Mass

1. The Achilles tendon inserts on the calcaneus at a distance of 8cm from the axis of the ankle joint. If the force generated by the muscles attached to the Achilles tendon is 3000 N and the moment arm of this force about the ankle joint axis is 5 cm, what torque is created by these muscles about the ankle joint?



The 5 cm is the moment arm (effort arm). $T = F \perp d = 3000N(0.05m) =$ 150 Nm

2. An athlete is doing a knee extension exercise using a 100-N dumbbell strapped to her ankle 40 cm from her knee joint. She holds her leg so that the horizontal distance from her knee joint to the dumbbell is 30 cm.



a. For this position, what torque is created by the dumbbell about the axis through her knee joint.

Since gravity works vertically, the 30 cm distance should be used since it will be perpendicular to the force of gravity working through the weight.
$T = F \perp d = 100N(0.30m) =$ 30 Nm

b. If the moment arm of the knee extensor muscles is 4 cm about the knee joint axis, what amount of force must these muscles produce to hold the leg in the position described? Ignore the weight of the leg.

The torque due to the weight must be equal in magnitude, but opposite in direction.

$30Nm = F_{muscle}(0.04m)$ $\qquad F_{muscle} = \dfrac{30Nm}{0.04m} = 750\ \text{N}$

3. What can a hurdler do to minimize the amount of vertical effort in clearing a hurdle?

By positioning the body in a way to keep the center of mass clearance as low as possible, the hurdler will not need to jump as high. This can be done by bringing the lead leg up parallel to the ground, the trunk and arms relatively low, and getting the trail leg to have a minimal clearance of the hurdle.

4. A hurdler's knee is 0.97 m above ground level. The ankle is 0.91 m above ground level. What is the height of the center of mass of the shank (lower leg)? The length percent for the shank is 47.5%.

$$CM_Y = Y_{Proximal} + L\%(Y_{Distal} - Y_{Proximal}) = 0.97m + 0.475(0.91m - 0.97m) = 0.94\ \text{m}$$

5. What could a gymnast do to increase her stability when she is landing on the balance beam from a flip.

- Maximize the base of support. Placing the feet in a way to have a large base of support will increase stability.
- Lower the center of gravity at landing by flexing at the knees and hip and creating a low arm position.
- Wrap the feet around the beam slightly to add the ability to produce larger torques in opposition to a potential falling direction.