

1. [25 points total] Statics

Here, we analyze the effects of changing the location of the tibial joint contact force **J** from a posterior point **P** to an anterior point **A** within the knee joint as depicted in the picture below. For both cases, assume that the ground reaction force **GRF** is unchanged, and that the *orientation* of the quadriceps muscle force **Q** is also unchanged. Treat this as a 2D statics problem and ignore the weight of the leg.

- i) [15 points] Use the picture below and a graphical *three-force vector triangle* approach to estimate the change in the magnitude of the muscle force **Q** when the contact point on the tibia changes from point **A** to point **P**. Express your answer as a ratio (value for point **A** / value for point **P**).



ii) [10 points] Continuing from part (i), estimate the ratio of the magnitudes of the patellar-femoral contact force (F_{PF-A}/F_{PF-P}) acting at point S for these two situations, namely, for having tibial-femoral contact at points A and P from part (i). Assume that point S remains unchanged.

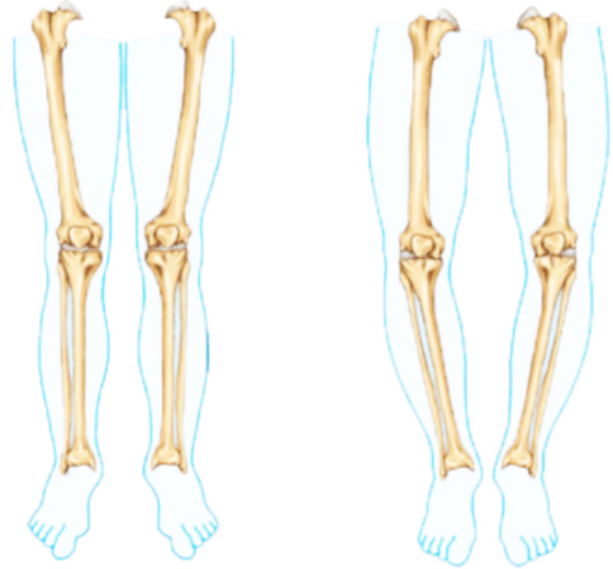


2. [25 points total] Joint Stability

In answering each of the following questions, draw a free-body diagram, perform an equilibrium analysis, and explain your answer.

- i) [10 points]** A bow-legged individual (“varus” alignment) has knee joints that are displaced laterally from normal anatomic position (“normal” alignment), in which the knee joint is directly over the ground reaction force.

Would you expect the contact force on the medial tibial condyle during standing to be higher or lower for a bow-legged individual compared to someone with normal bone alignment?



Normal Alignment

Varus Alignment

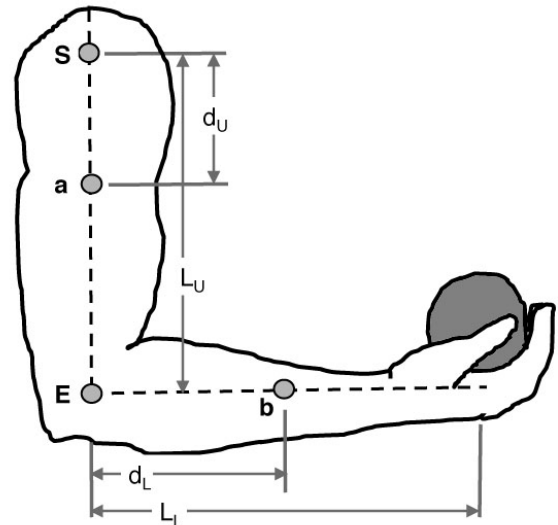
ii) [15 points] For clinical problems with plantar fasciitis, the plantar fascia ligament can get damaged due to overloading. Using a free-body analysis of the free body shown on the right, explain how variation in the details of a person's bone anatomy may explain why, *for the same body-weight and external loading*, some people are more likely to get plantar fasciitis than others.



3. [50 points total] Dynamic Analysis

An athlete holds a solid steel ball and then rapidly rotates his arm *counter-clockwise* about the shoulder with an angular velocity of $\omega \text{ rad/s}$ and a *counter-clockwise* angular acceleration of $\alpha \text{ rad/s}^2$ while keeping the elbow and wrist joints rigid. At the given instant, assume the following:

- planar dynamics;
- the point **S** is the instantaneous center of rotation of the rigid arm/hand/ball system;
- the upper arm (mass of M_U) is vertical;
- the forearm and hand (combined mass of M_L) are horizontal, as shown;
- the center of mass of the upper arm is at point **a** and the center of mass of the lower arm (forearm + hand) is at point **b**;
- the steel ball acts as a point mass M_b ;
- the mass moment of inertia for the arm segments (about their respective mass centers) are denoted by I_U for the upper arm and by I_L for the forearm including the hand but not the ball.



i) [15 points] Draw a *fully labeled* free body diagram, including any accelerations, of the *lower arm-ball combined system* (i.e. from the elbow down), showing the resultant force and moment at the elbow joint. Show your sign convention.

- ii) **[35 points]** For this planar dynamic problem, write out the three equations of motion for the *lower arm-ball combined system* in terms of *only the quantities* provided in the problem description and the loads and dimensions shown in your free body diagram.