A. Teaching notes for the guided questions of Simulation I

When the arm is extended, the arm length is 38.9% of the height of a person H_P.[1] The free body diagram can be simplified with only four forces JRF_s, F_{del}, W_{bal} and the weight of an arm W_A. Unlike objects with homogeneous mass distributions, the centers of mass of the body are not at geometric centers. The center of mass of an arm is 46.0% of the arm length from the shoulder joint end. For the segment of arm, $W_A = W_{FA} + W_{UA}$ is 4.8% of the weight of a person W_P. F_{del} is approximately at 25.0% of arm length with $\theta_{del} = 15.0°$.[2]

Here are the sample guided questions.

- "Assuming a person keeps the same pose, how does the force on deltoid muscle and the joint reaction force on a shoulder depend on the weight of the ball?"

  Students are expected to control variables to ensure W_P and H_P are constant. They should notice large magnitudes of F_{del} and JRF_s even when W_{bal} is small or zero. We guide students to understand the mechanism behind of these large values by looking back at their equation setup and calculation.

- "Does JRF_{sh}, the horizontal component of JRF on the shoulder change with the weight of ball? Please run the simulation to verify your prediction and explain the results."

  With this guided question, they will also notice that when W_{bal} changes, the JRF_{sv} changes, the same happens with the JRF_{sh}, even though the weight of the ball is downward.

- "How do you predict F_{del} and JRF_s change for an adult who is shaped differently? Such as a person who is taller/shorter, or heavier/lighter. How about a child who is shorter and lighter? Please apply Simulation I to verify your prediction."

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[1] Stanley Plagenhoef, F. Gaynor Evans and Thomas Abdelnour,"Anatomical data for analyzing human motion," Res. Q. Exerc. Sport," **54**, 169–178 (1983).

[2] Howard D. Goldick, *Mechanics, Heat and the Human Body: An Introduction to Physics*, (Pearson, New Jersey, 2001), p. 99.