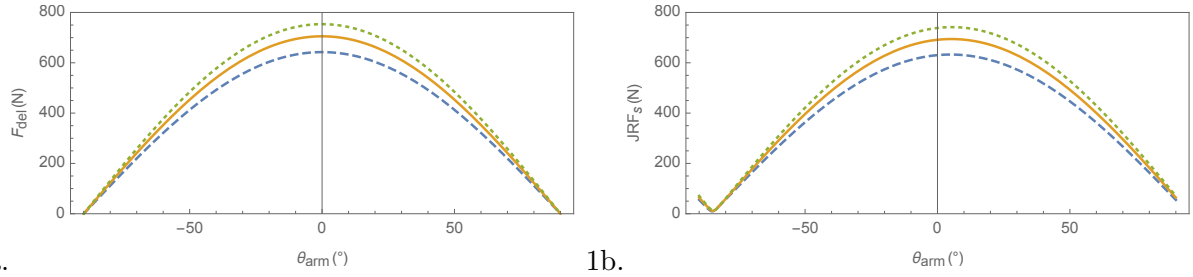
### A. Teaching notes for the guided questions of Simulation II

- "Keeping $W_{bal}$ constant, how do $F_{del}$ and $JRF_s$ change as the arm moves up and down? Where is the pose easiest and most challenging? How do differently shaped people change the results? Do the results match with your life experiences?"

In order to answer the questions, students can be guided to collect data and make plots for different groups of people. Fig.1 shows that $F_{del}$ and $JRF_s$ change with $\theta_{arm}$ and different Body Mass Index (BMI) values. BMI is a person's weight in kilograms divided by the square of height in meters.




1a. 1b.

FIG. 1. The dependence of $F_{del}$ and $JRF_s$ on $\theta_{arm}$ for an adult with the height of 1.7 m, when $W_{bal}$= 30.0 N. The blue dashed, orange solid and green dotted curves are for BMI = 18.5, 25.0, 30.0 $kg/m^2$ respectively. The three BMI values are chosen based on the range of underweight (<18.5) $kg/m^2$, normal (18.5, 25.0) $kg/m^2$, overweight (25.0,30.0) $kg/m^2$ and obese (>30.0) $kg/m^2$ for an adult.[1]

The students in our teaching practice were able to identify the easiest and most challenging positions. The easiest positions, where $F_{del}$ and $JRF_s$ have minimum values in Fig. 1, happen when the arm holding the ball downward or upward, which matches with how we carry loads in daily life. The most challenging moment happens when the arm is held in a horizontal direction. Fig. 1 also shows that the people with higher BMI experience comparably more forces on the deltoid muscle and the shoulder joint for the same position; the difference becomes larger when the positions become more challenging.

There is a slight shift of the easiest and most challenging positions for $JRF_s$. The shoulder experiences the maximum force when the arm is slightly above the horizontal and the shoulder feels most comfortable when the arm holding downward but slightly off. People normally don't notice it in life not just because of the small magnitude but also because

forces on muscle cause instantaneous and primary feelings, but forces on joints usually cause more permanent and serious injuries. The application of physics to the human body provides valuable insight into the injury potential of various motions and exercises.

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[1] Adult Overweight and Obesity, Centers for Disease Control and Prevention, <https://www.cdc.gov/obesity/adult/defining.html>.