IN REPLY

In reply: Ultrasound gel dispensing: There may be more going around than centripetal acceleration

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To the Editor,

I thank Dr. Turkstra for his comments¹ providing us with advanced engineering explanations for my previously described technique.² My distant physics classes are certainly no match for his master's degree in mechanical engineering; nonetheless, I will use this opportunity to explain my reasoning further.

In retrospect, my original graphic was somewhat misleading on the description of a single arc of rotation, but was done for the purpose of simplification. In reality, I do use a more complex motion that can be broken down into three phases around different axes of rotation (shoulder, elbow, and wrist), with my greatest force output always occurring during the final "wrist snap" action. Therefore, a more precise graph would feature three joints with distinct arcs of rotation. It is true that gel displacement occurs at the end rather than midway during the global motion, probably because it is only when we reach the third arc of rotation (wrist) that the angular velocity of the bottle reaches the magnitude necessary for the resulting centripetal/centrifugal forces to surpass static friction.

In the electronic supplemental material, Dr. Turkstra makes a convincing mathematical argument that lateral acceleration is often significantly greater than centripetal acceleration. Aside from the order of magnitude, we must also consider the direction vector of these forces. By definition, centripetal and lateral acceleration are perpendicular to one another. To my understanding, when holding the bottle in the position shown in the graphic,¹ if

lateral acceleration were most relevant, we should expect the gel to stick to the lateral part of the container at the end of the motion since the direction of the vector of lateral acceleration is always tangential to the arc of rotation. In practice, however, we rather see the gel amass in the top portion of the bottle, which I find more consistent with the outward seeking effect of centrifugal force.

We can also hypothesize different models. For example, a bottle could be slowly brought to constant angular velocity by repeated circular movements around the shoulder joint, thereby limiting any impact of angular acceleration. This is based on the principle that an object moving with fixed angular velocity will have an angular acceleration of 0. Although very inconvenient, this method does bring us closer to isolating centripetal acceleration from other confounding forces. As for the gravity issue, I suggest a model where the bottle could be rotated in the horizontal plane, rather than in the vertical plane, thereby negating any contribution of gravity during the downward phase of motion.

Conflicts of interest None declared.

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