Kinematically similar basketball free throws have surprisingly different muscle contraction velocity profiles

[1]Daniel A. Hagen, [1]Steven Caja, [2]Suraj Chakravarthi Raja, [1,3]Francisco J. Valero-Cuevas

[1]Department of Biomedical Engineering, [2]Department of Electrical Engineering, [3]Division of Biokinesiology & Physical Therapy, USC

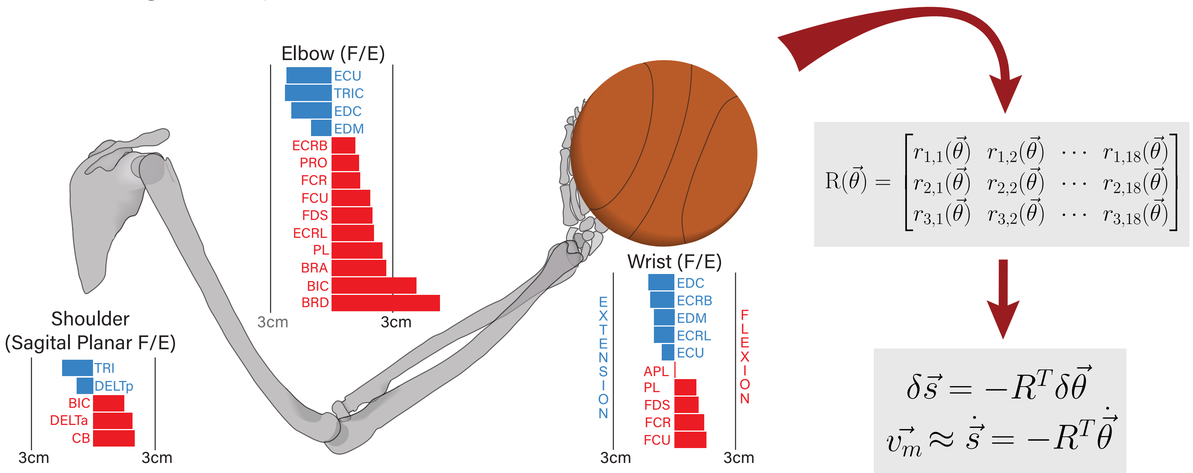
Question

Is there a difference between a good shot and a good looking shot in basketball?

- Recent work re-emphasizes that neural control of limb movements is in fact overdetermined, with the rotation of a few joints determining the length changes in many muscles [1, 2].
- As Sherrington pointed out, if even one eccentrically contracting muscle fails to silence its stretch reflex appropriately, the movement is disrupted [3].
- Throws requiring larger eccentric contractions require larger alpha-gamma control and are therefore more prone to error, while large concentric contractions reduce power output.
- Therefore we investigated whether kinematically similar throws could exhibit large differences in eccentric and concentric muscle fiber contraction velocities.

Methods

We used an 18-muscle planar arm model to calculate a family of 100,000 random, feasible shoulder, elbow and wrist joint rotations that produced stereotyped basketball shots with different hand trajectories but identical starting and ending hand positions and velocities.

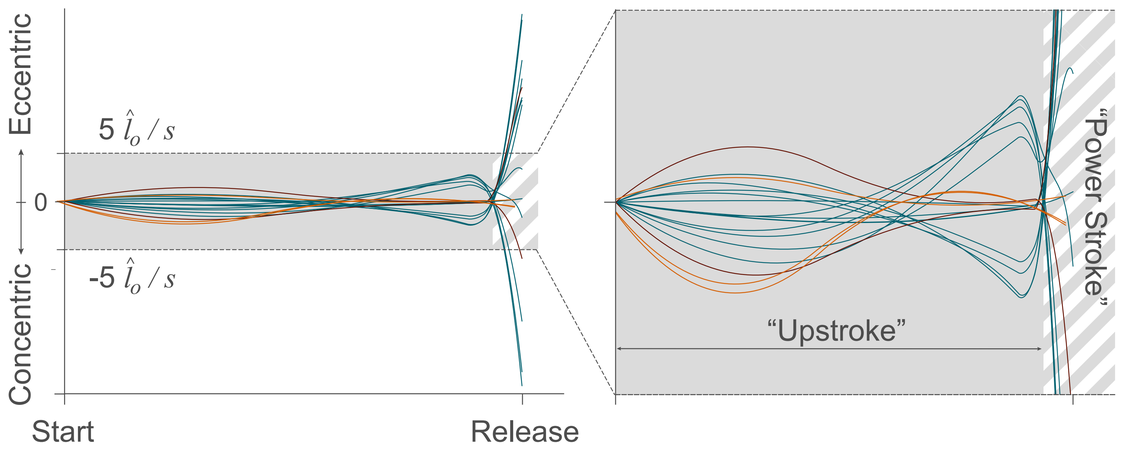


$$\mathrm{R}(\vec{\theta}) = \begin{bmatrix} r_{1,1}(\vec{\theta}) & r_{1,2}(\vec{\theta}) & \cdots & r_{1,18}(\vec{\theta}) \\ r_{2,1}(\vec{\theta}) & r_{2,2}(\vec{\theta}) & \cdots & r_{2,18}(\vec{\theta}) \\ r_{3,1}(\vec{\theta}) & r_{3,2}(\vec{\theta}) & \cdots & r_{3,18}(\vec{\theta}) \end{bmatrix}$$

$$\delta\vec{s} = -R^T \delta\vec{\theta}$$

$$\vec{v_m} \approx \dot{\vec{s}} = -R^T \dot{\vec{\theta}}$$

Utilizing a posture specific moment arm matrix it was possible to estimate fiber velocities for each of the 18 muscles from the time derivatives of the generated joint rotations (angular velocities) [1, 4, 5, 6].



Note: Orange traces reflect muscles that only cross the shoulder, maroon traces reflect the biceps and the triceps, and the teal traces reflect all other muscles. Zero crossings reflect instances where the wrist and elbow either remain motionless relative to each other or change the direction of their contraction.

Then for each throw, muscle velocity profiles were generated. The maximal eccentric and concentric contraction velocities were recorded for each muscle during the "upstroke" phase and the Euclidean norms of these values produced measures for eccentric and concentric contraction levels, respectively.

References:

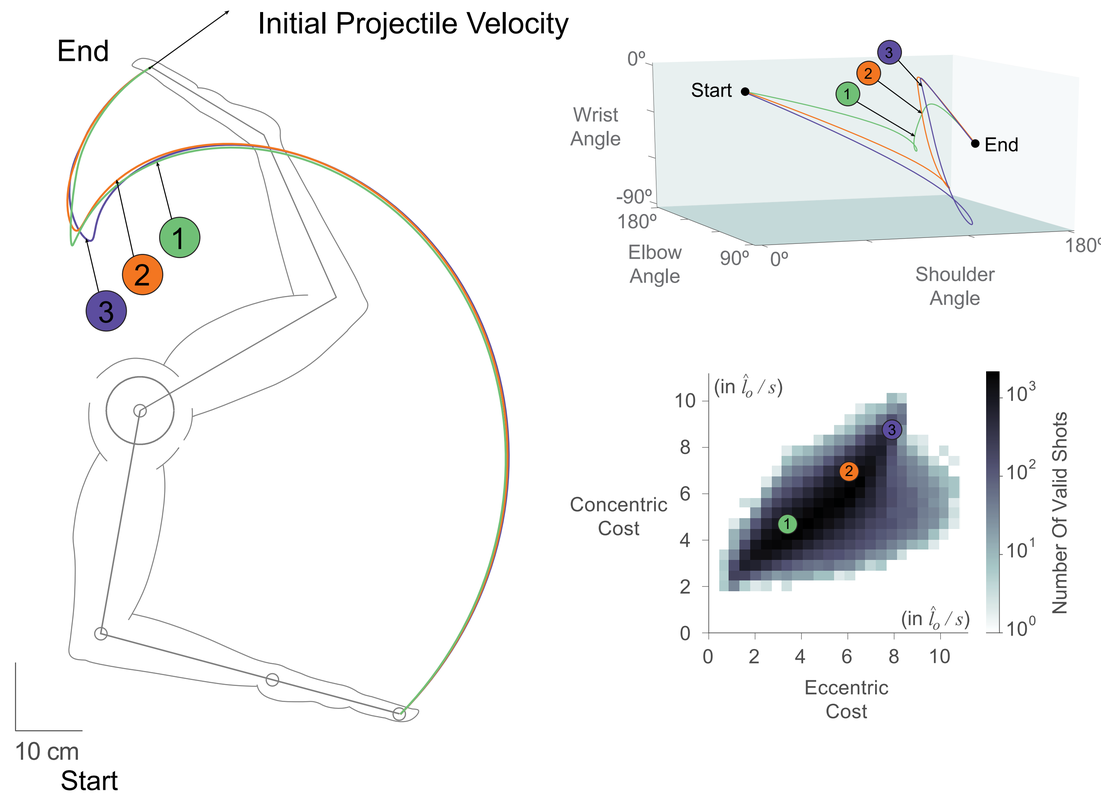
[1] Valero-Cuevas, FJ, *Fundamentals of Neuromechanics*, Springer-Verlag London, 2016. [2] Valero-Cuevas, F, Cohn, B, Yngvason, H, & Lawrence, E, *J Biomech*, **48**(11), 2887-2896, 2015. [3] Sherrington, C.S. *Exp. Physiol.*, **6**(3) 252-310, 1913. [4] Winter, DA, *Biomechanics and motor control of human movement: Fourth edition*, Elsevier B.V., 2013. [5] Ramsay, JW, Hunter, BV, & Gonzalez, RV, *J Biomech*, **42**(4), 463-473, 2009. [6] Holzbaur, KR, Murray, WM, & Delp, SL, *Annals of Biomedical Engineering*, **33**(6), 829-840, 2005.

(Additional references available upon request.)

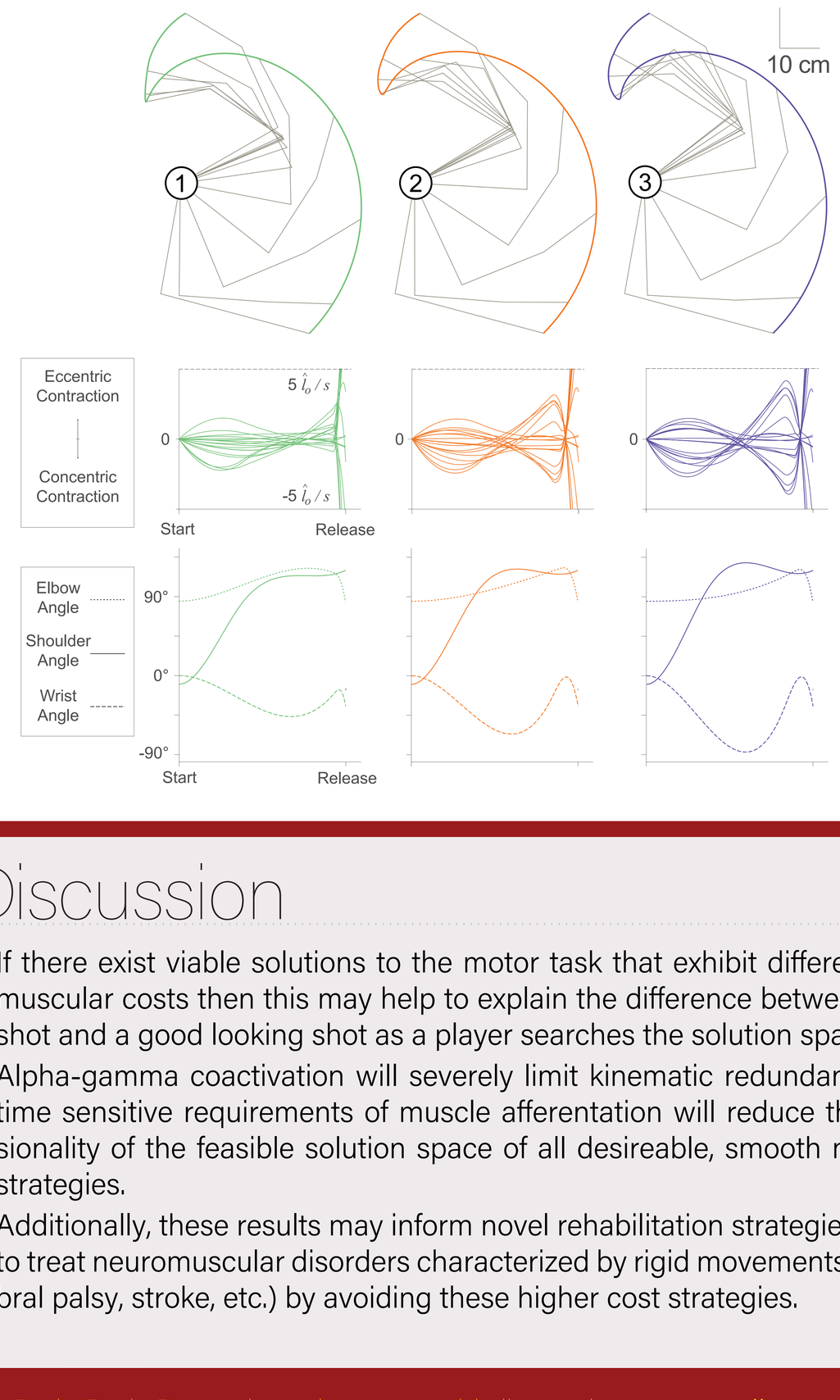
Acknowledgements:

We thank the University of Southern California for facilities provided during the course BME/BKN 504, and Dr. Emily Lawrence who laid the foundation for this research and shared her prior work.

Results



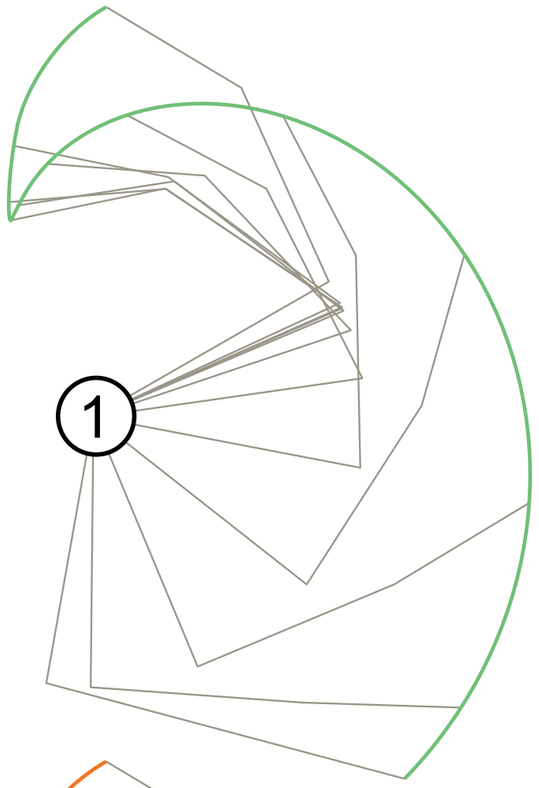
Illustrated here are three kinematically similar hand trajectories that demonstrate different levels of eccentric and concentric contractions (top panel, bottom right), different configuration space trajectories (top panel, top right and bottom panel, bottom traces) as well as different muscle fiber velocity profiles (bottom panel, middle traces)

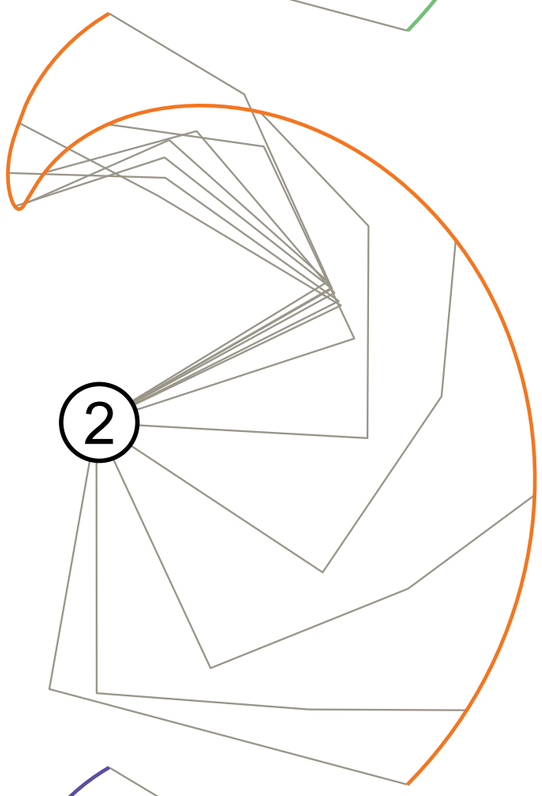


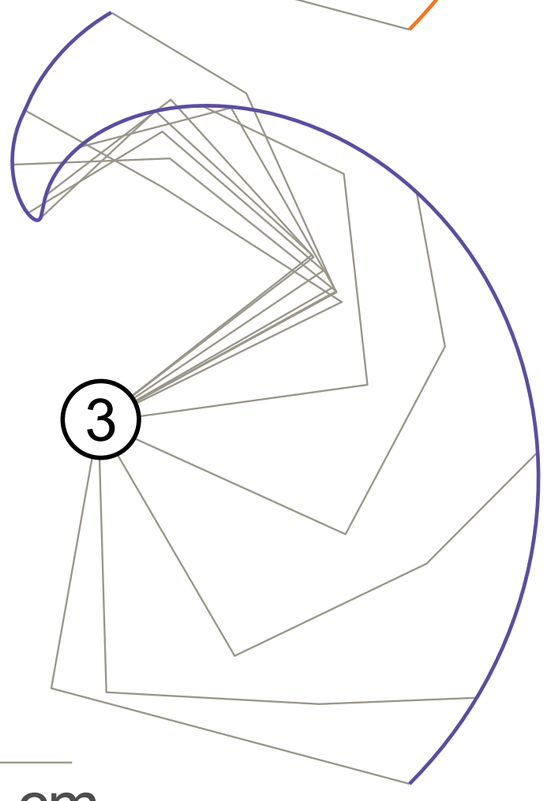
Discussion

- If there exist viable solutions to the motor task that exhibit different neuromuscular costs then this may help to explain the difference between a good shot and a good looking shot as a player searches the solution space.
- Alpha-gamma coactivation will severely limit kinematic redundancy as the time sensitive requirements of muscle afferentation will reduce the dimensionality of the feasible solution space of all desireable, smooth movement strategies.
- Additionally, these results may inform novel rehabilitation strategies that aim to treat neuromuscular disorders characterized by rigid movements (i.e. cerebral palsy, stroke, etc.) by avoiding these higher cost strategies.

The Brain Body Dynamics Lab bbdl.usc.edu dhagen@usc.edu



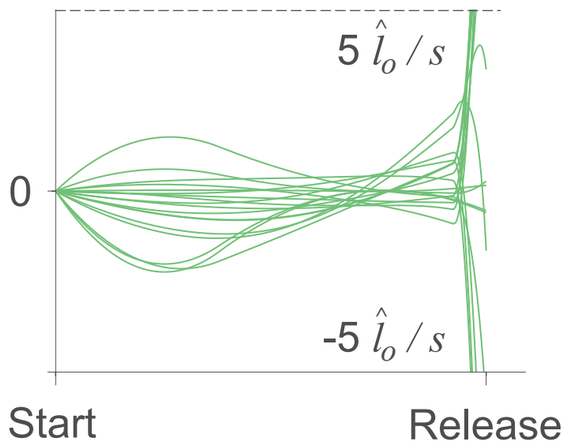


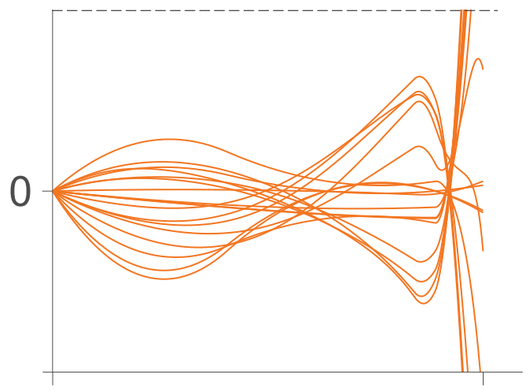


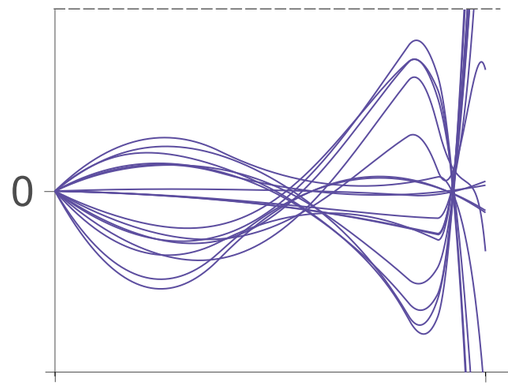
10 cm

Eccentric Contraction

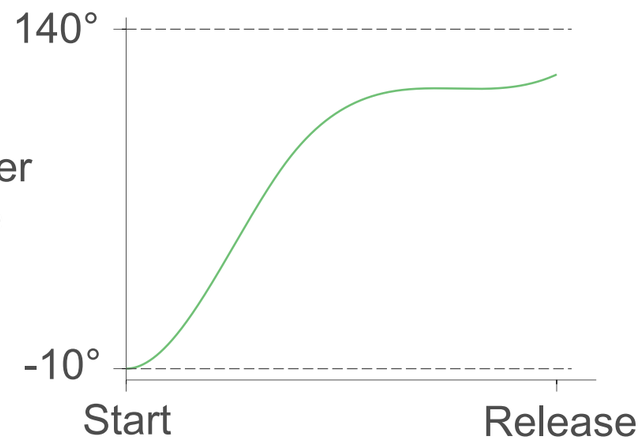
Concentric Contraction

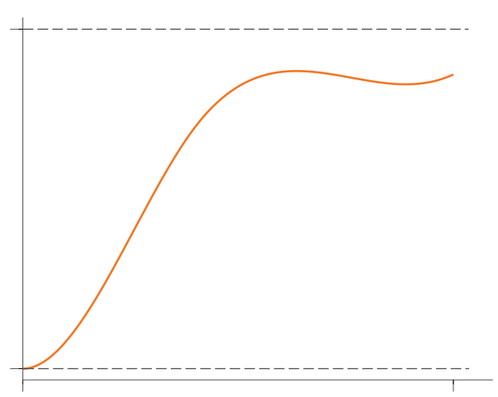


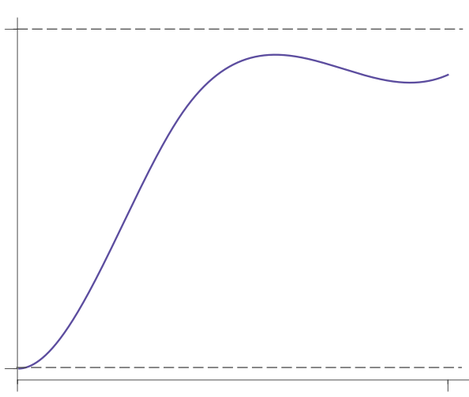




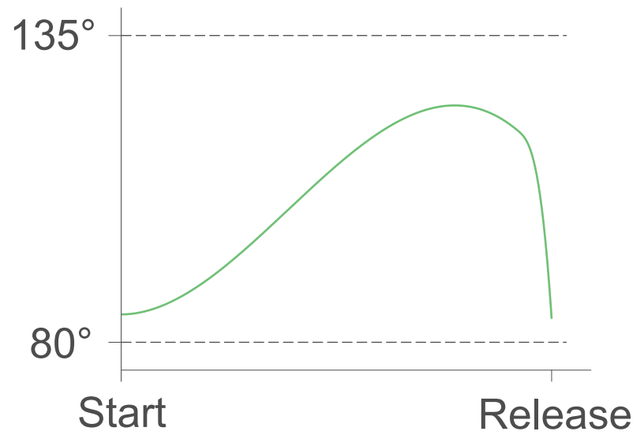
Shoulder Angle

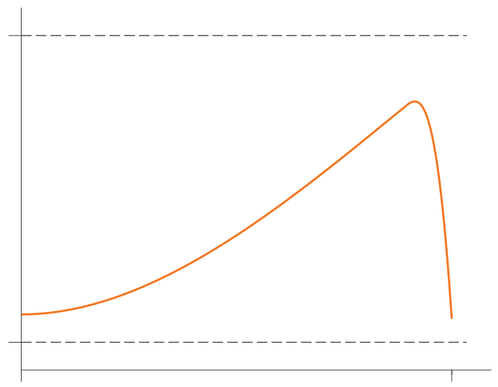


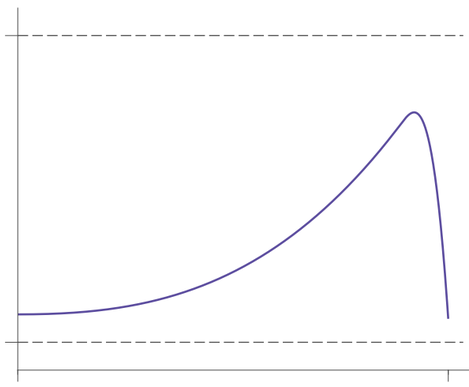




Elbow Angle







Wrist Angle