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

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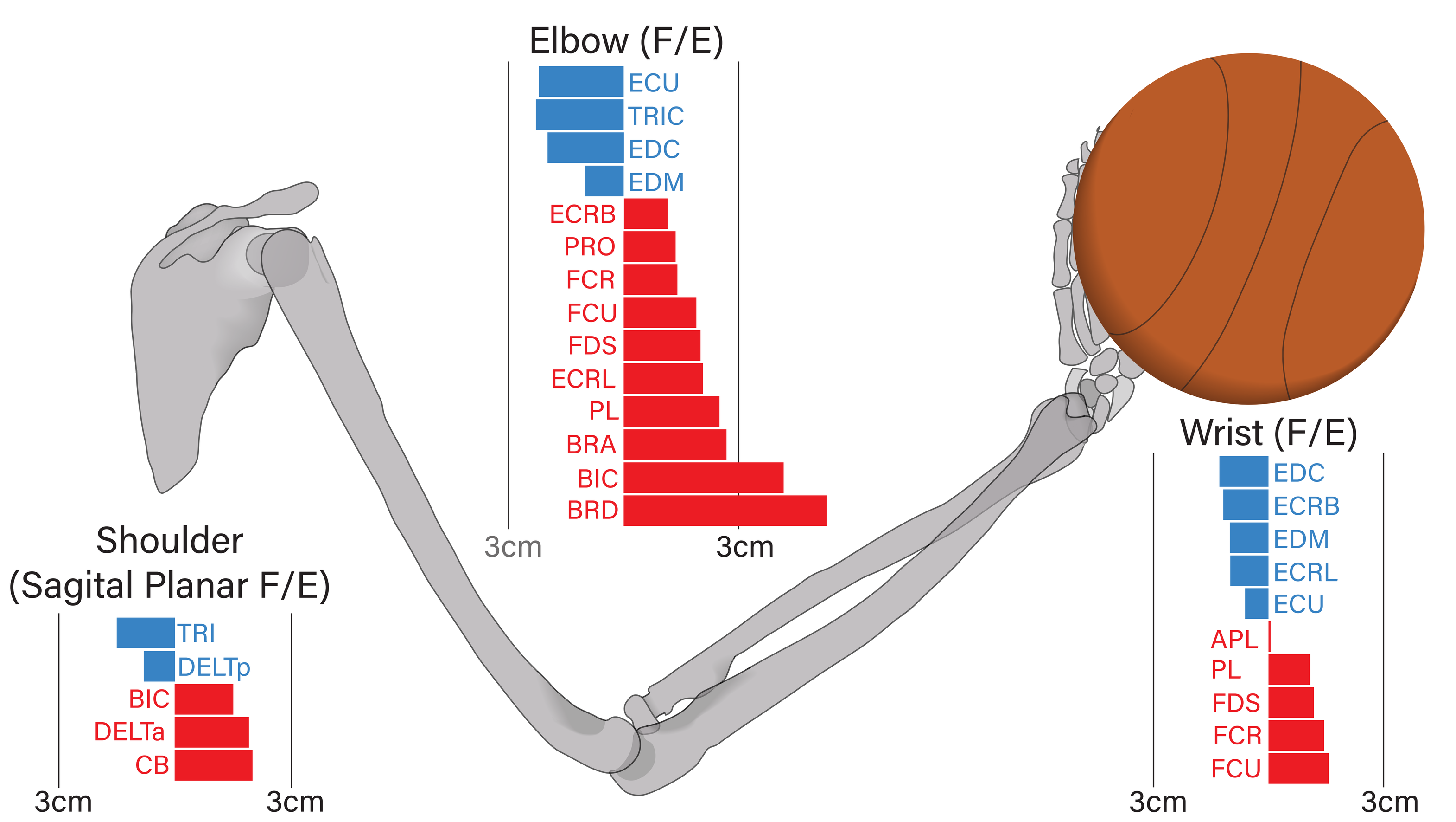
Question

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

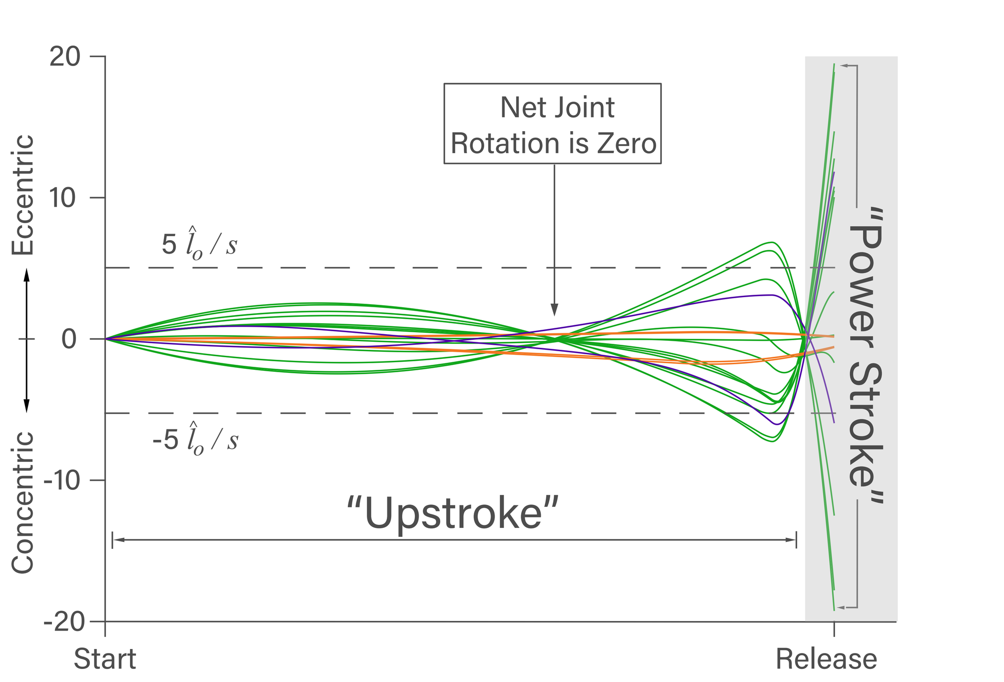
We used an 18-muscle planar arm model to calculate a family of 100,000 random, feasible shoulder, elbow and wrist joint rotations that produced stereotyped basketball shots with different hand trajectories but identical starting and ending hand positions and velocities.



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].

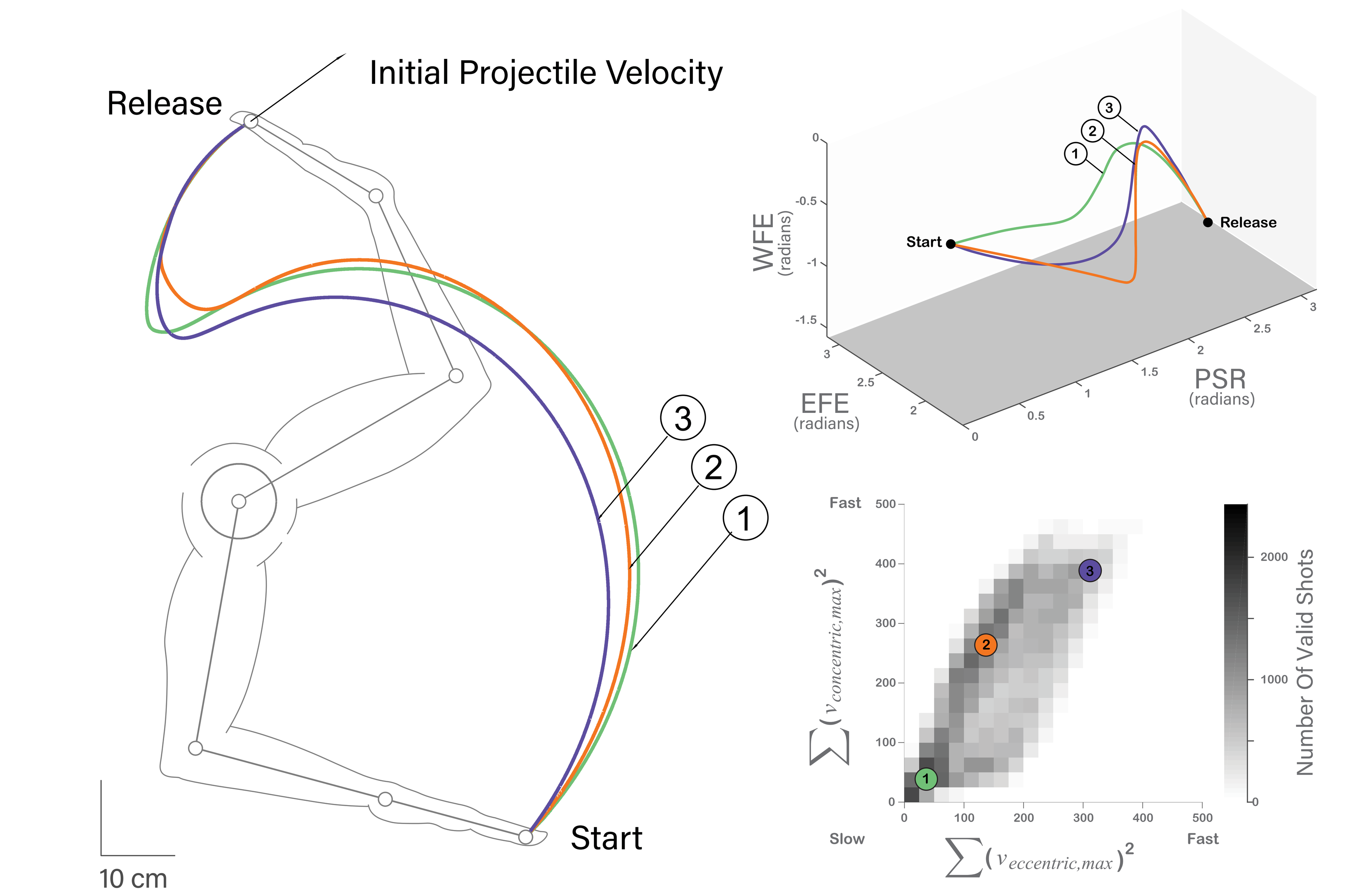
$$\mathrm{R}(\vec{\theta}) = \begin{bmatrix} r_{1,1}(\vec{\theta}) & r_{1,2}(\vec{\theta}) & \cdots & r_{1,18}(\vec{\theta}) \\ r_{2,1}(\vec{\theta}) & r_{2,2}(\vec{\theta}) & \cdots & r_{2,18}(\vec{\theta}) \\ r_{3,1}(\vec{\theta}) & r_{18,2}(\vec{\theta}) & \cdots & r_{3,18}(\vec{\theta}) \end{bmatrix} \longrightarrow \begin{aligned} \delta\vec{s} &= -R^T\delta\vec{\theta} \\ \vec{v_m} \approx \dot{\vec{s}} &= -R^T\dot{\vec{\theta}} \end{aligned}$$

Then for each throw, a muscle fiber velocity profile was generated and the magnitude of eccentric and concentric contractions was taken as the sum of squared of the largest contraction each muscle experienced during the "upstroke" phase.

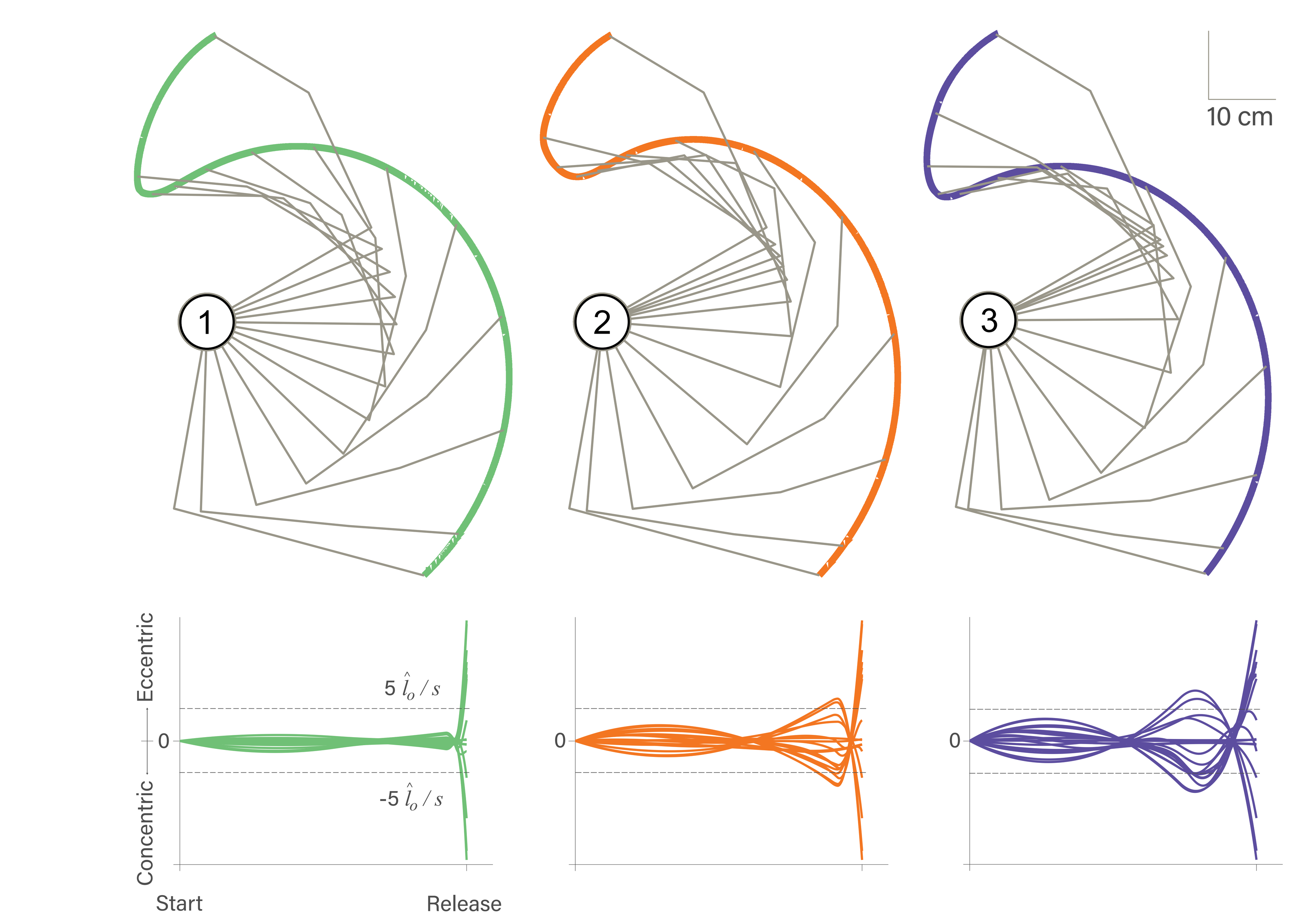


Note: Orange traces reflect muscles that only cross the shoulder, purple traces reflect the biceps and the triceps, and the green traces reflect all other muscles. Zero crossings reflect instances where the wrist and elbow either remain motionless relative to each other or change the direction of their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

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) as well as different muscle fiber velocity profiles (bottom panel)



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.
- If we consider the set of all possible motor task solutions, the large differences between kinematically similar solutions may also help to constrain the solution space, making the system less overdetermined.
- Kinematic redundancy would then be severely limited as the requirements of the muscle afferentation would reduce the dimensionality of the feasible solution space.

References:

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(Additional references available upon request.)

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