Analysis of the Various Pulling Movements

Michael Pozzi

Group Partners: Alex Yao, James Tang

Group

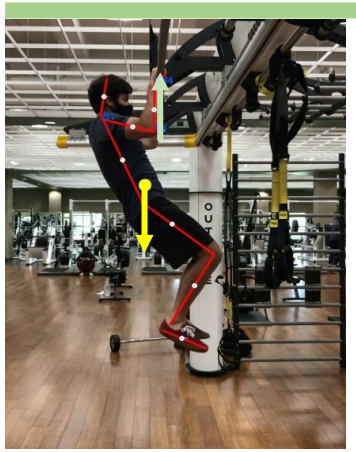
- Tasks:
  - Regular Pull Up – Alex Yao
  - Explosive Pull Up – James Tang
  - Countermovement Pull Up – Michael Pozzi
- Common Interests among members:
  - All are interested in upper body strengthening in hypertrophy whether it be for performance in a climbing setting, calisthenic setting, or aesthetic setting

My Task: Countermovement Pull Up

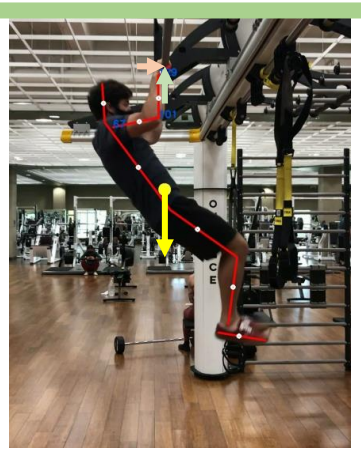
- About Me: I am a competitive rock climber, so dynamic and explosive strength in the pulling motion is incredibly important and studying this activity could provide insight into more optimal training
- Mechanical Objective: Use countermovement motion in order to store energy and release it in order to maximize vertical velocity on release
- Stakeholders: Gymnasts, Climbers, Calisthenic Athletes, and general fitness enthusiasts
- Why the care: Using the countermovement pull up can help train the velocity aspect of the pull up motion in order to maximize power output

Motion Analysis

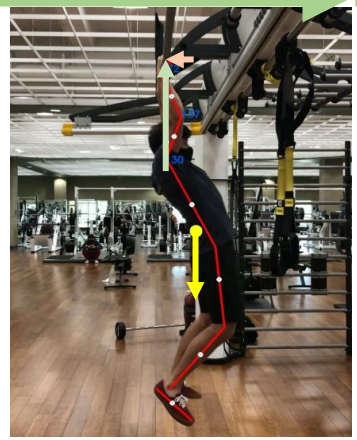
Countermovement Phase → Primary Phase



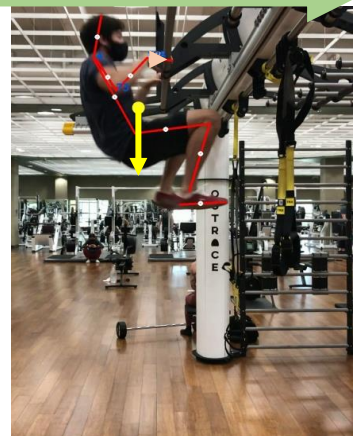
Start
Frame: 2
Time: 0.03 s



RFv Min
Frame: 40
Time: 0.67 s



RFv Max
Frame: 67
Time: 1.12 s



Release
Frame: 102
Time: 1.70 s

Frame Rate: 60 Hz

Time Between frames: 1/60 s

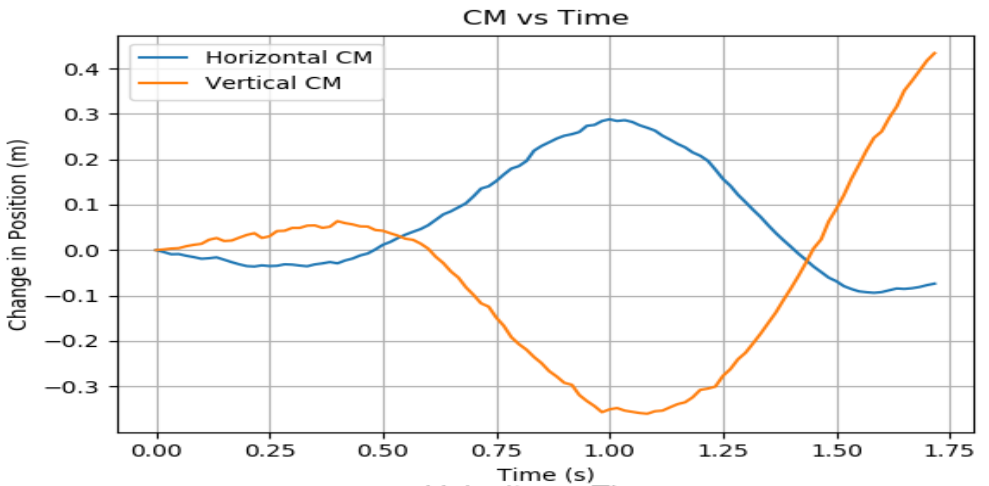
Elapsed time of task: 1.667 s

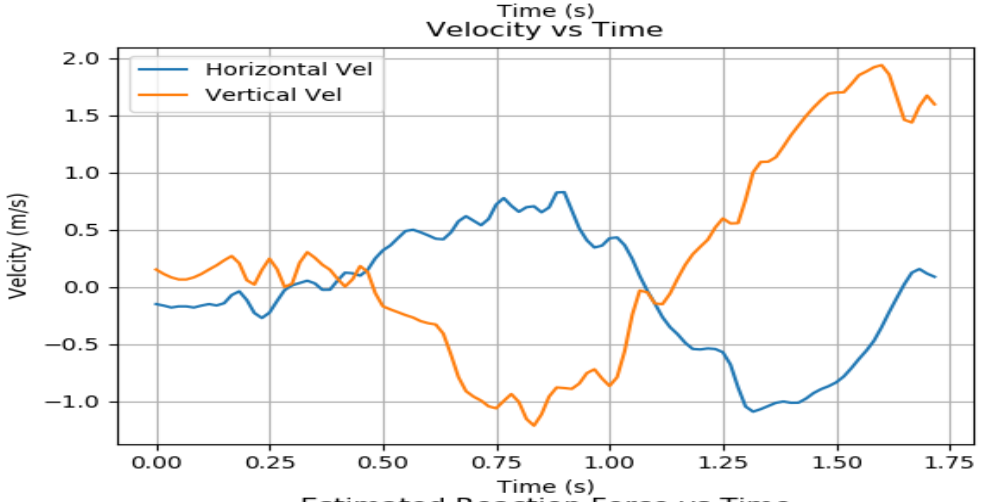
BW:

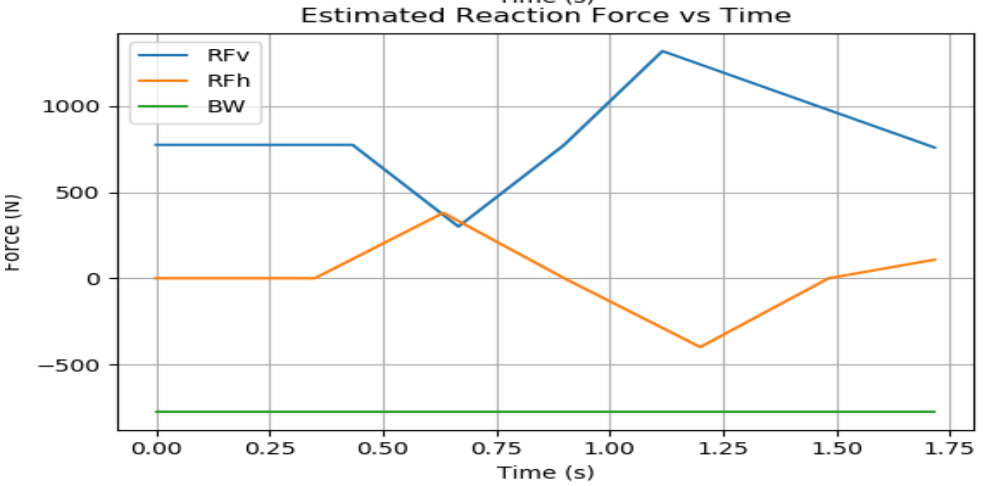
RFv:

RFh:

Mechanical Objective: Use countermovement motion in order to store energy and release it in order to maximize vertical velocity on release

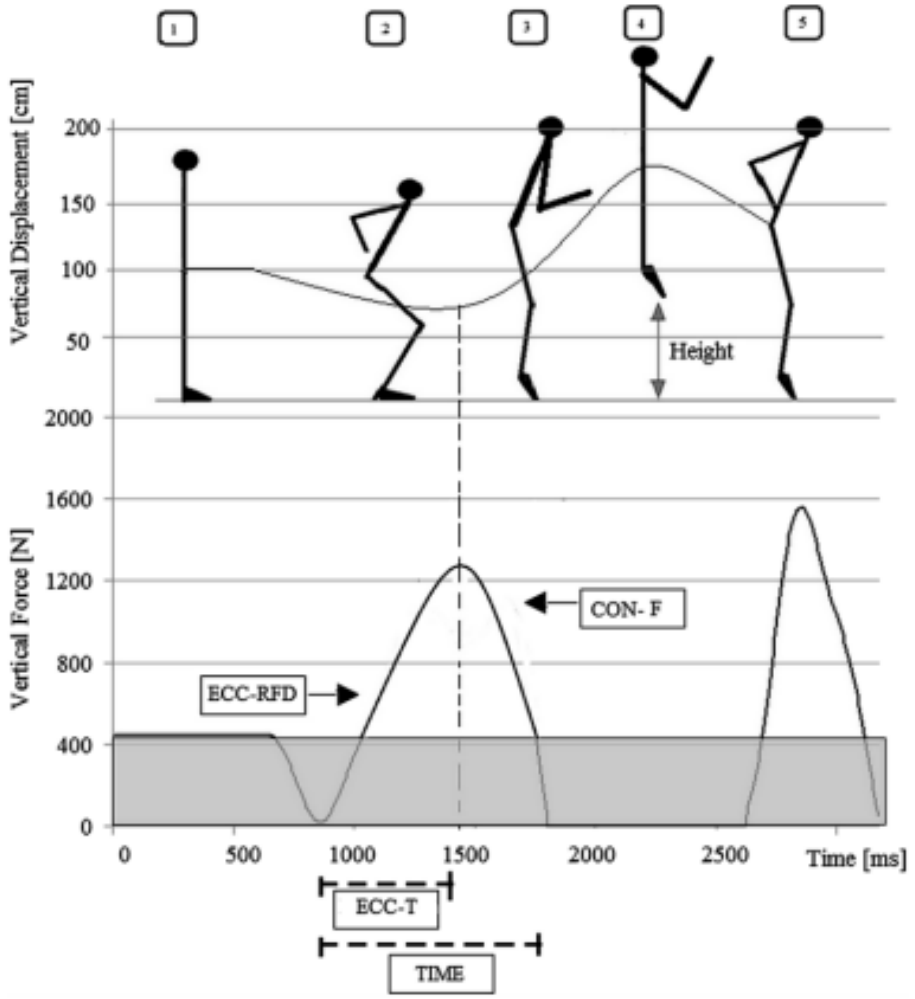


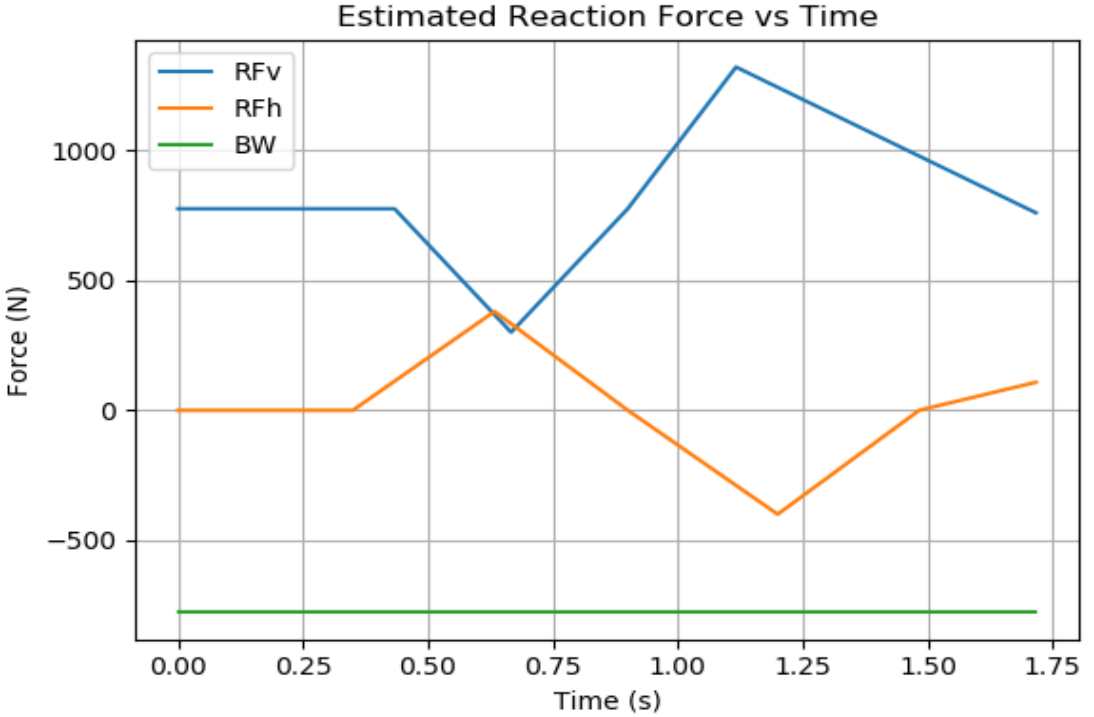


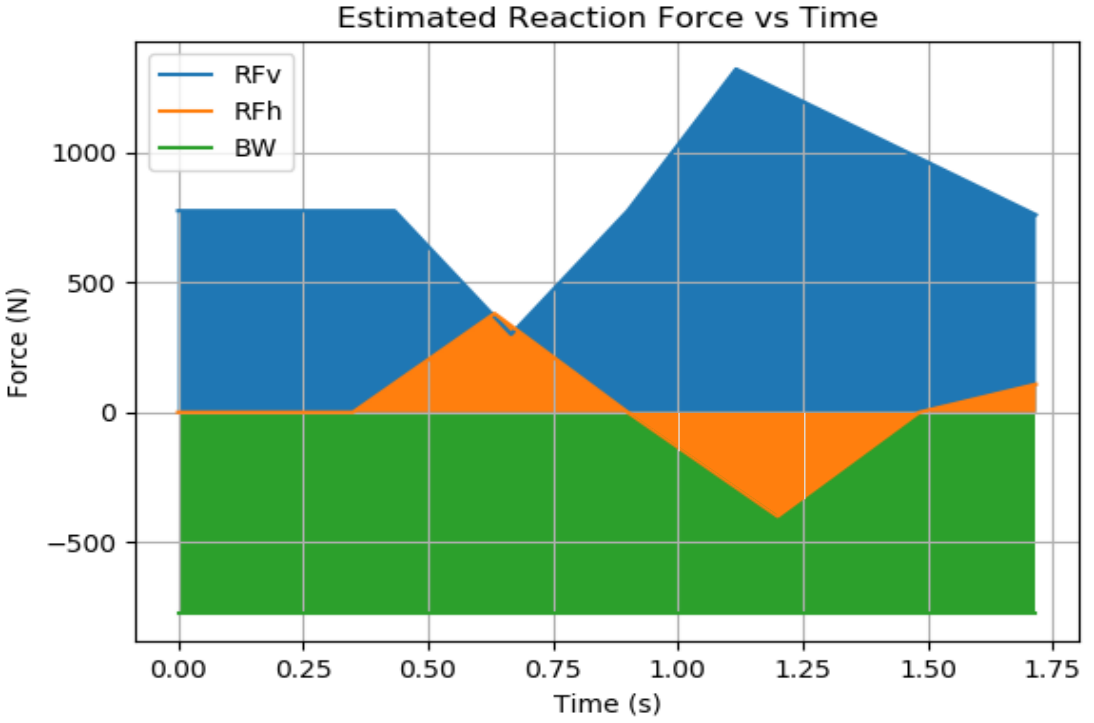


Example Curve/Task:

*There is very little to no peer reviewed literature that includes a force/time curve of the countermovement pull up. To include some data, we hypothesized that the countermovement jump would be analogous given the similar motion patterns in the vertical direction







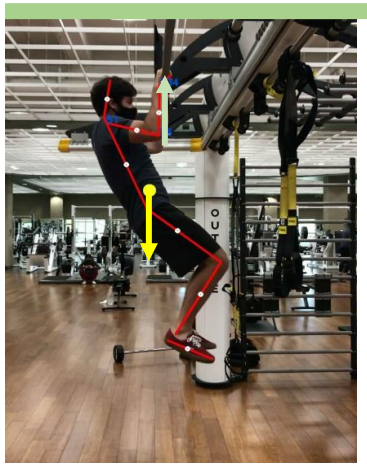
Interval of Interest:
Total Time: 1.70 sec
Total Frames: 102 samples at 60 Hz

Citation:

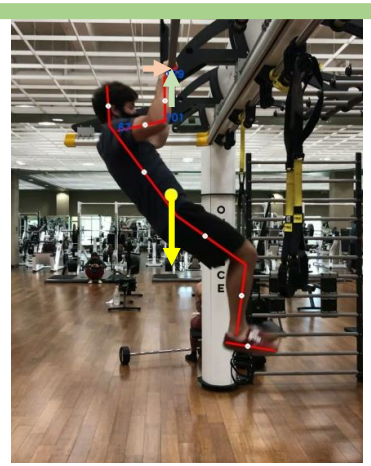
Laffaye, Guillaume, Wagner, Phillip & Tombleson, Tom. (2014). Countermovement Jump Height: Gender and Sport-Specific Differences in the Force-Time Variables. Journal of Strength & Conditioning Research, 28, 1096-1105. https://doi.org/10.1519/JSC.0b013e3182a1db03

Horizontal Analysis

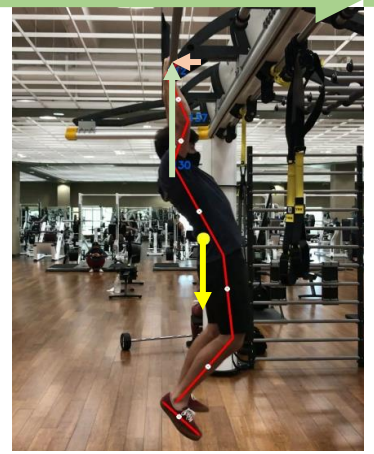
Countermovement Phase → Primary Phase



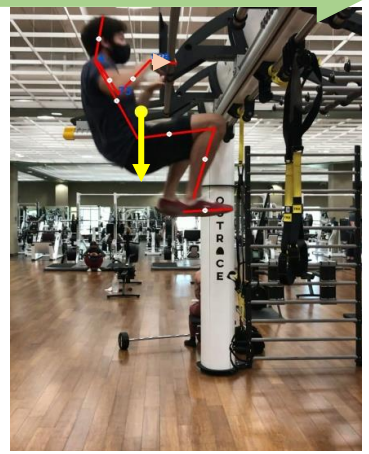
Start Frame: 2
Time: 0.03 s



RFvMin Frame: 40
Time: 0.67 s

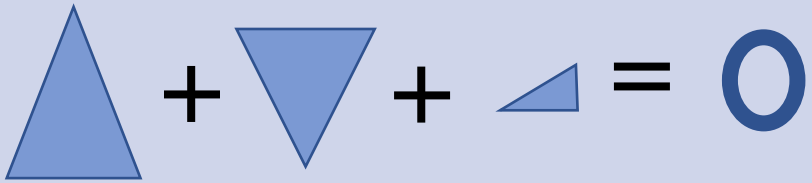


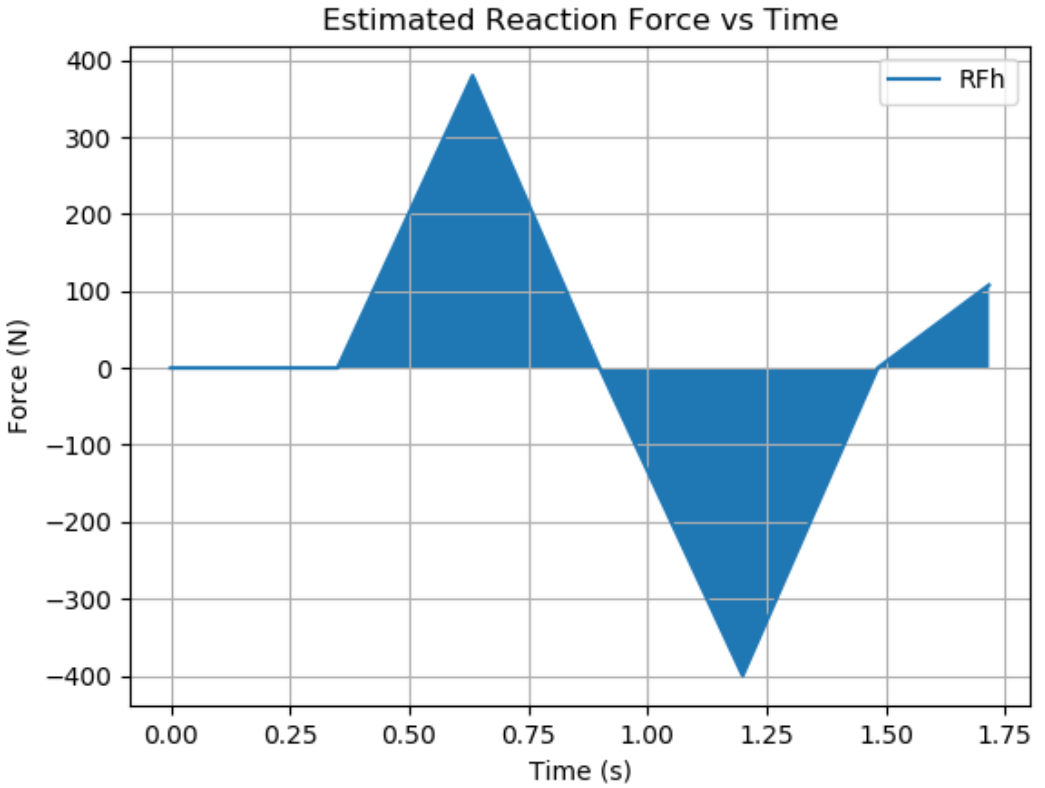
RFvMax Frame: 67
Time: 1.12 s



Release Frame: 102
Time: 1.70 s

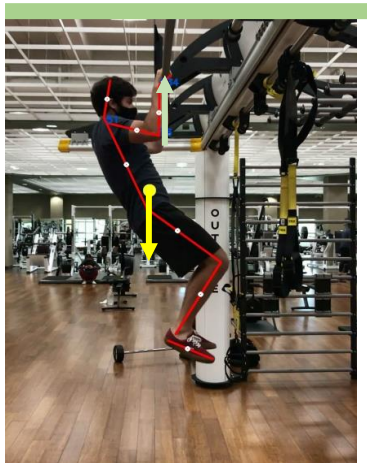
Net Horizontal Impulse [Ns] = ΔHoriz Momentum of the CM

General Equation	**$\Sigma F_x(t_2-t_1) = m(V_{h1} - V_{h2})$**
Conceptual Picture	*Three motions on the bar: Pull body toward bar, Push body away from bar, then pull body back towards bar before release 
Terms of Equation	$Impulse_{Pull\ 1} + Impulse_{Push} + Impulse_{Pull\ 2} = m \times 0$ => (-RFh x time) + (+RFh x time) + (-RFh x time) = 0
Hypothesized Values	(0.5)(0.55 s)(380 N) – (0.5)(0.575 s)(400 N) + (0.5)(0.225 s)(100 N) ≈ 0 *Values derived from velocity values and Impulse/Momentum relationship

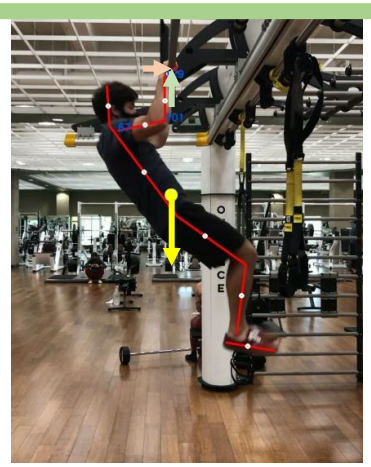


Vertical Analysis

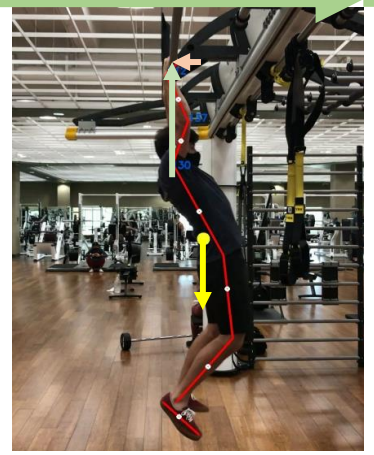
Countermovement Phase → Primary Phase



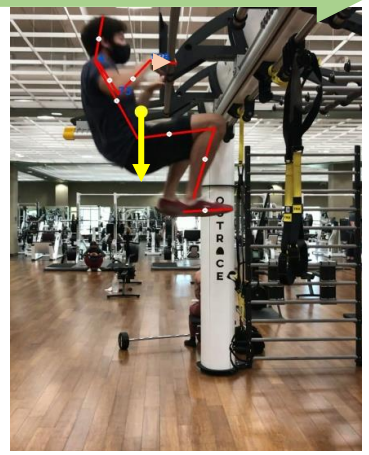
Start Frame: 2
Time: 0.03 s



RFvMin Frame: 40
Time: 0.67 s

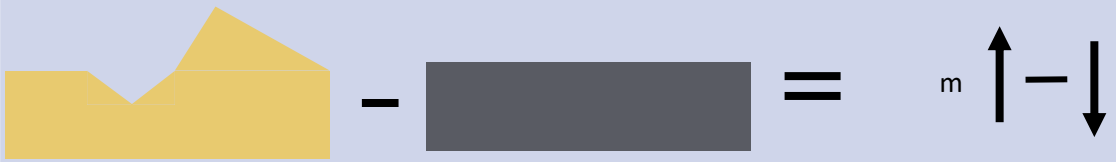


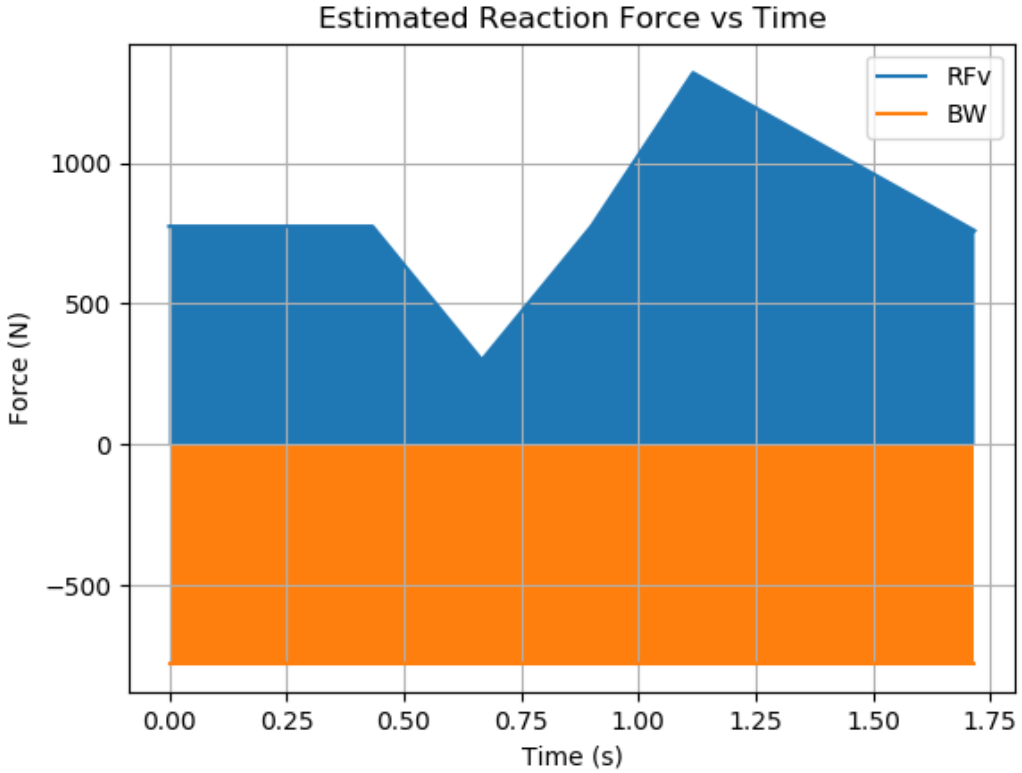
RFvMax Frame: 67
Time: 1.12 s



Release Frame: 102
Time: 1.70 s

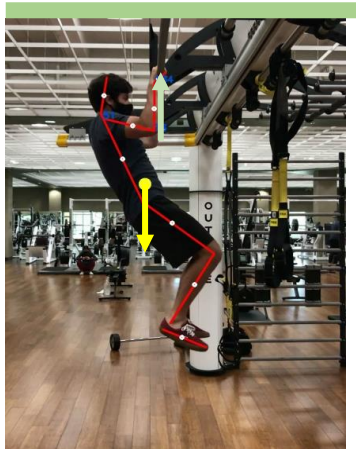
Net Vertical Impulse [Ns] = ΔVert Momentum of the CM

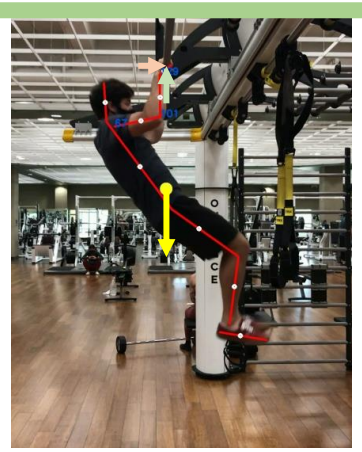
General Equation	**$\Sigma F_v(t_2-t_1) = m(V_{v1} - V_{v2})$**
Conceptual Picture	$Impulse_{vert}$ + (-) $Impulse_{BW}$ = $m(V_{v1} - V_{v2})$ 
Terms of Equation	$Impulse_{vert}$ + $Impulse_{BW}$ = $m(V_{v1} - V_{v2})$ => [RFv x time] + [-BW x time] = m (V_{v2})
Hypothesized Values	[-(0.5)(0.47 s)(475 N) + (0.5)(0.80 s)(545 N)]/(79 kg) ≈ 1.5 m/s

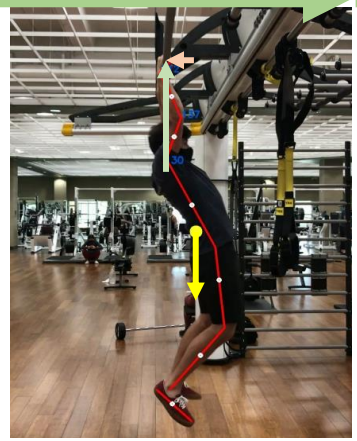


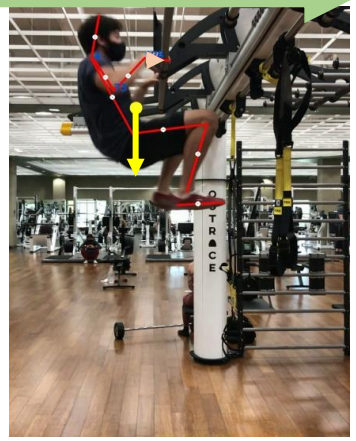
Net Angular Impulse

Countermovement Phase → Primary Phase

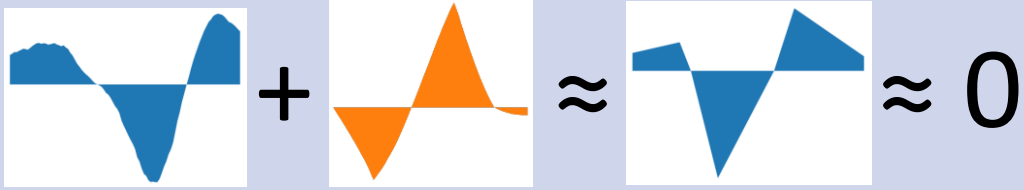

Start

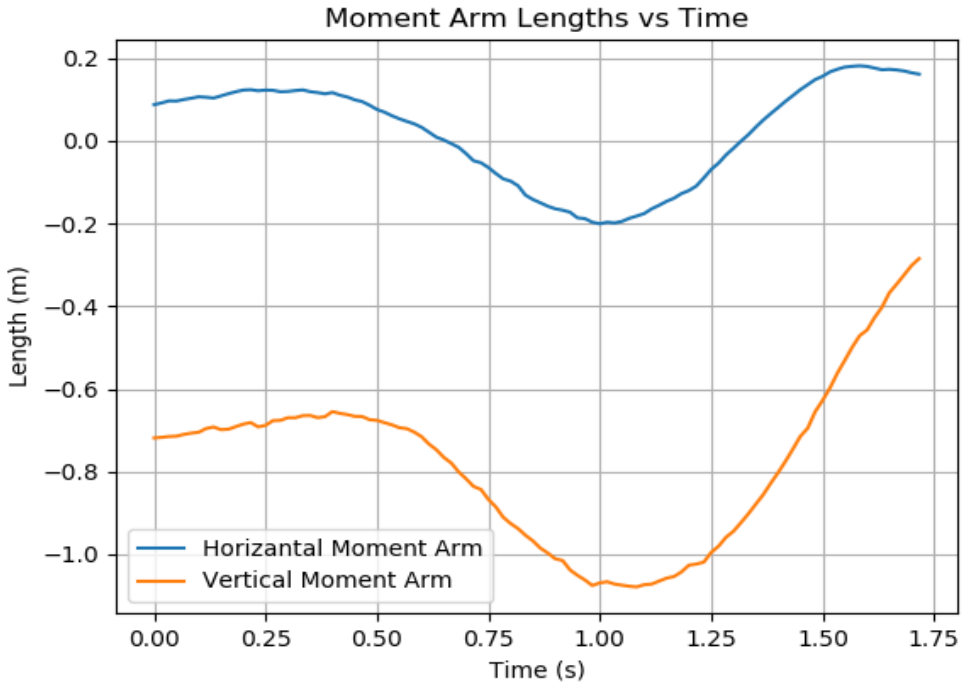

RFv Min

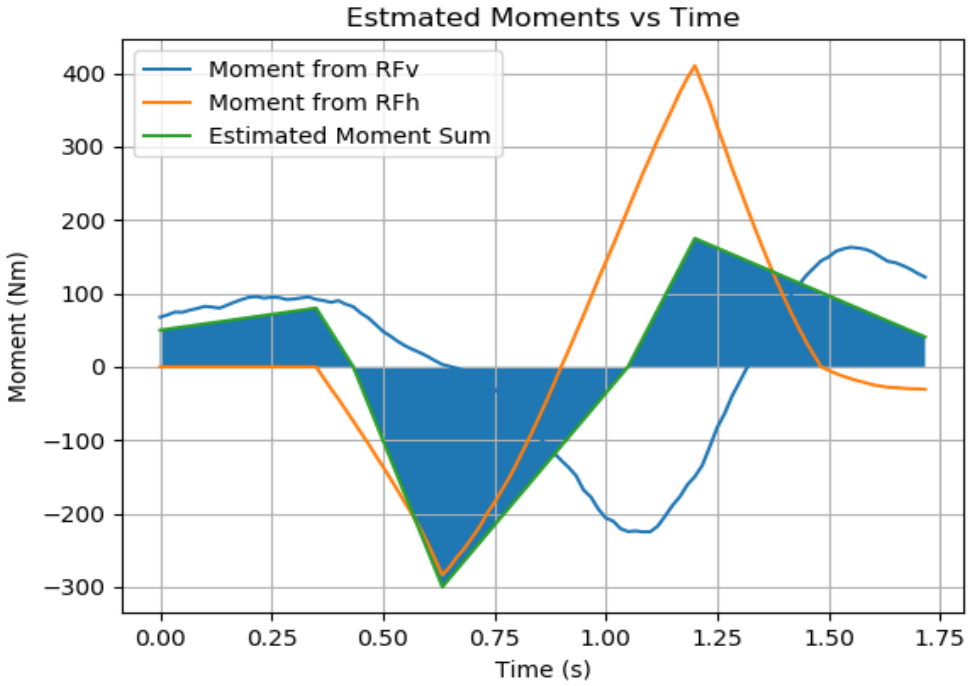

RFv Max


Release

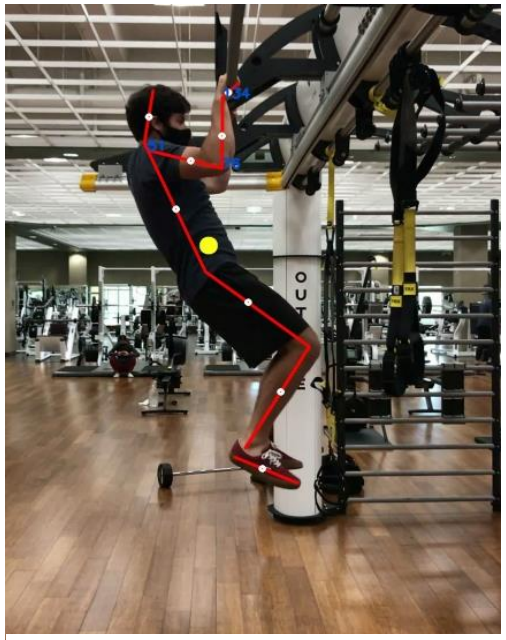
Net Ang Impulse [Ns] = Δ Ang Momentum about the CM

General Equation	**$\Sigma M(t2-t1) = \Delta H$** **$(RF_v*dx)(\Delta t) + (RF_h*dy)(\Delta t) = \Delta H$**
Conceptual Picture	Impulse Due Moment RFv + Impulse Due to Moment RFh = ΔH = 0 
Terms of Equation	$Impulse_{M\ due\ to\ Fx} + Impulse_{M\ due\ to\ Fy} = \Delta H$ $M_{Fx}(\Delta t) + M_{Fy}(\Delta t) = \Delta H$
Hypothesized Values	Area of the Sum of the Moments due to Reaction Forces: 25.95 Nms – 92.40 Nms + 67.34 Nms ≈ 2.42 Nms ≈ 0 Nms given estimation error

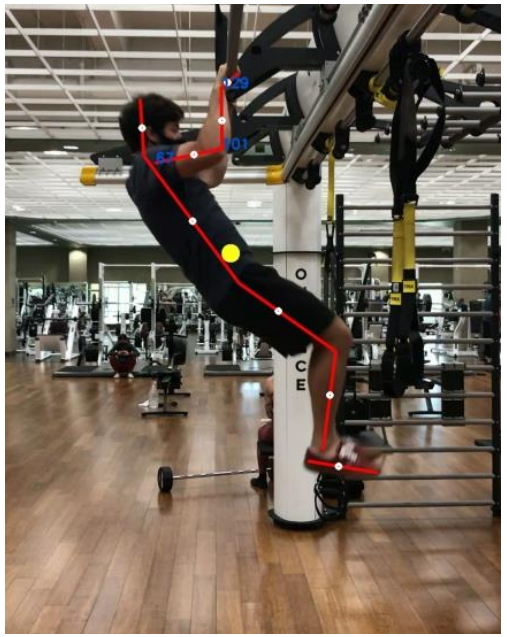




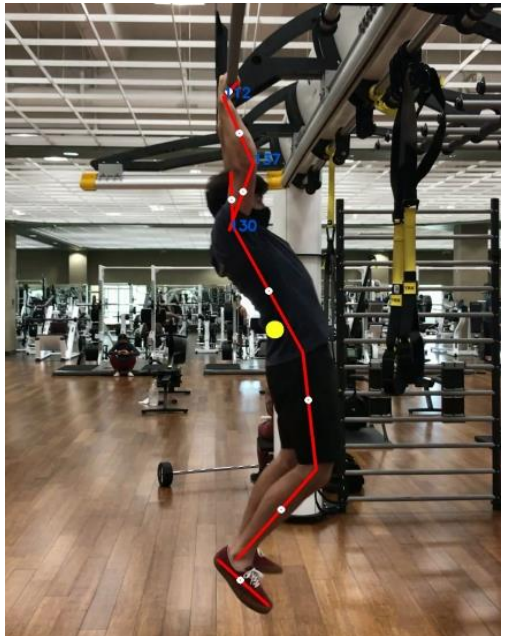
Joint Angle Analysis



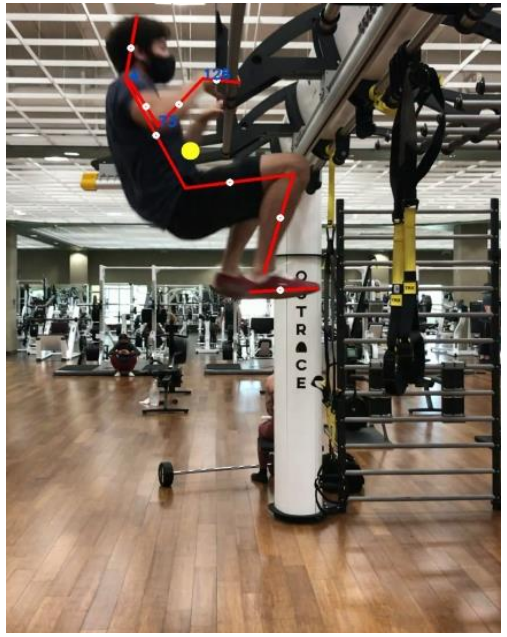
Start



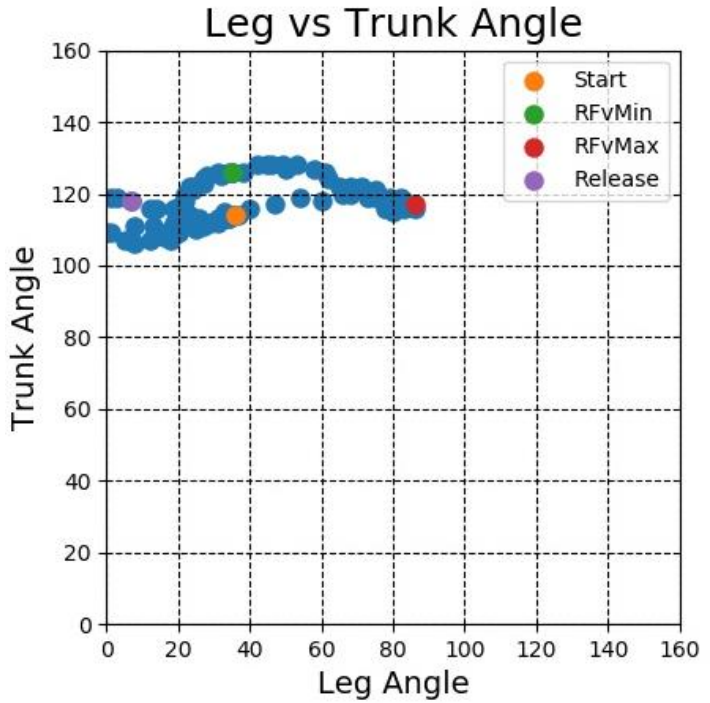
RFv Min

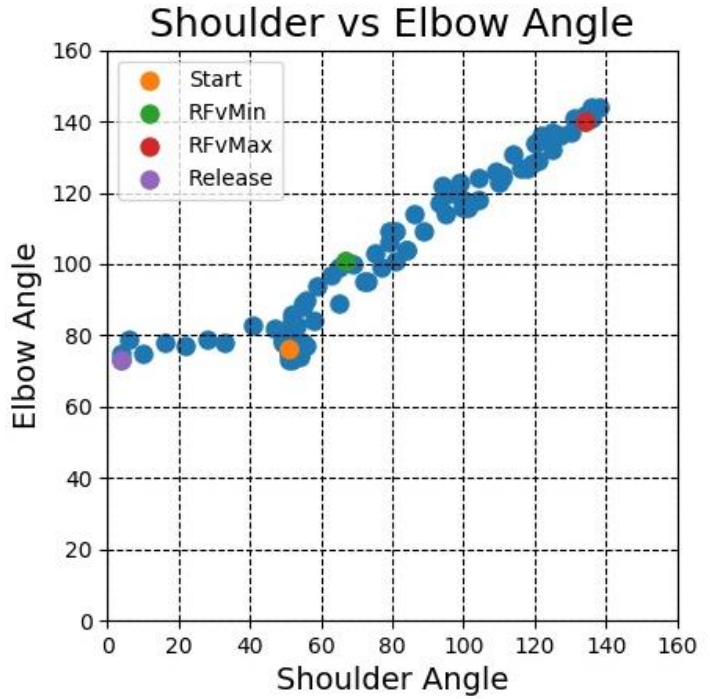


RFv Max

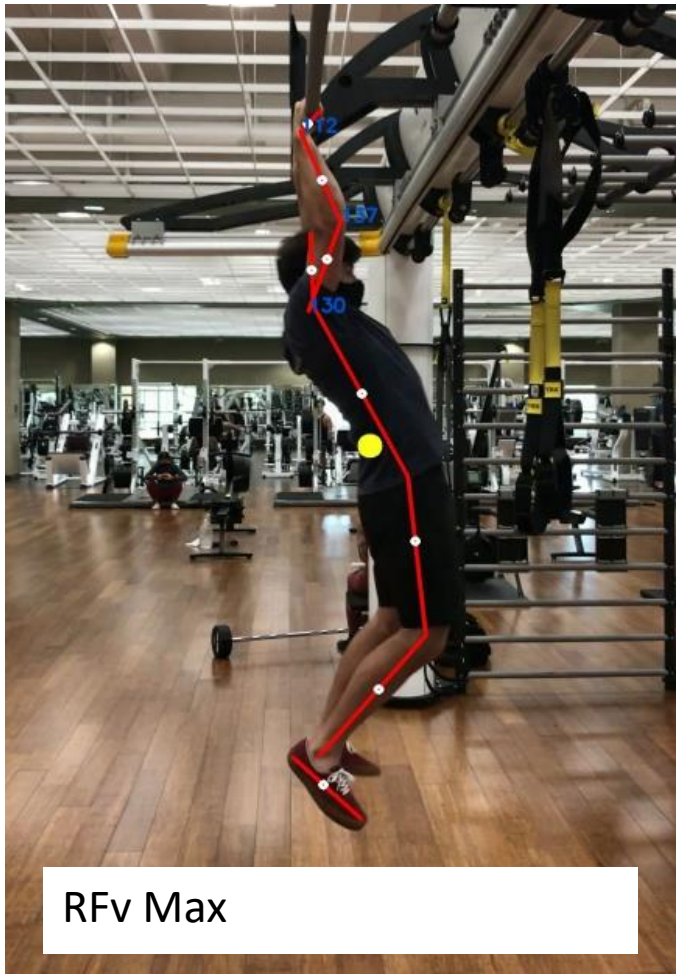


Release



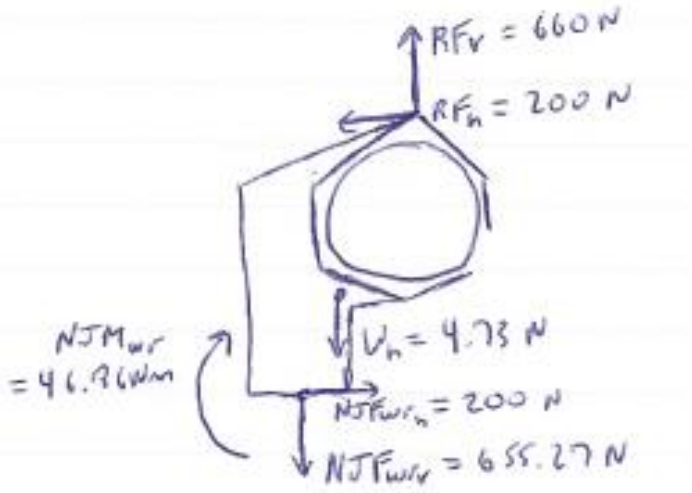


Joint Kinetics

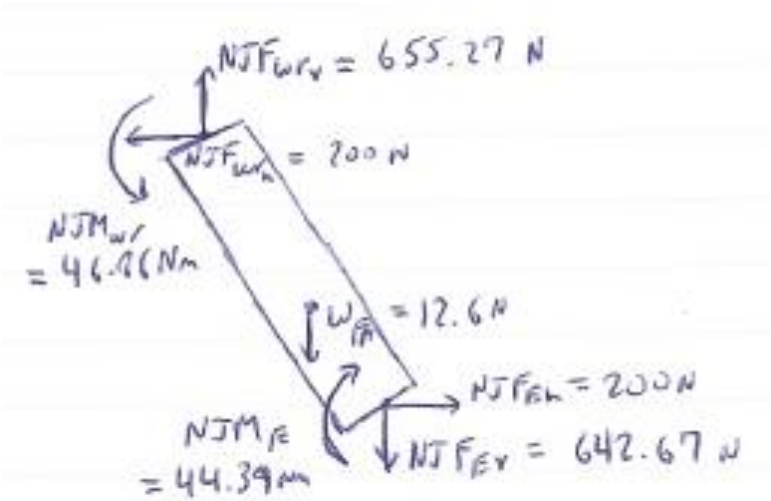


RFv Max

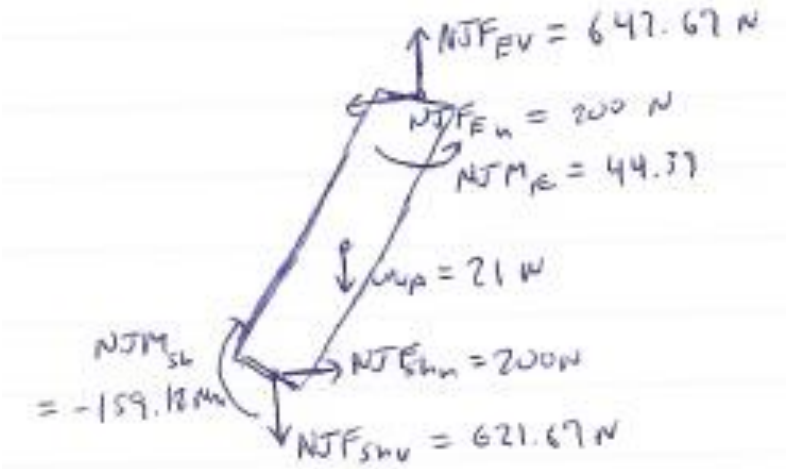
Hand @ RFv Max



Forearm @ RFv Max



Upperarm @ RFv Max

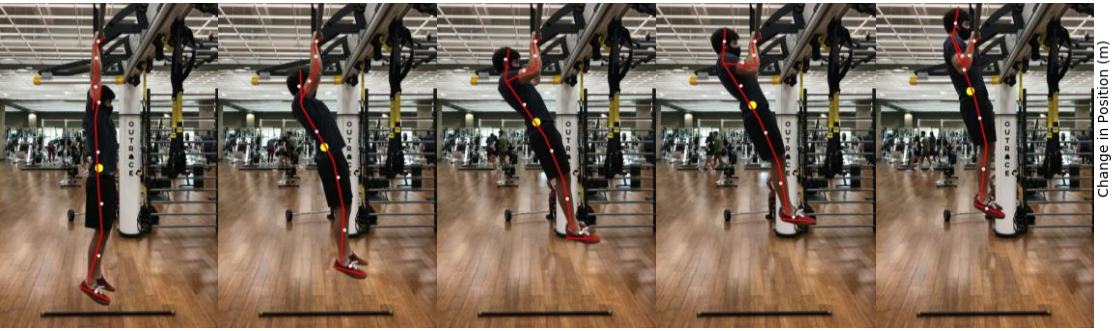


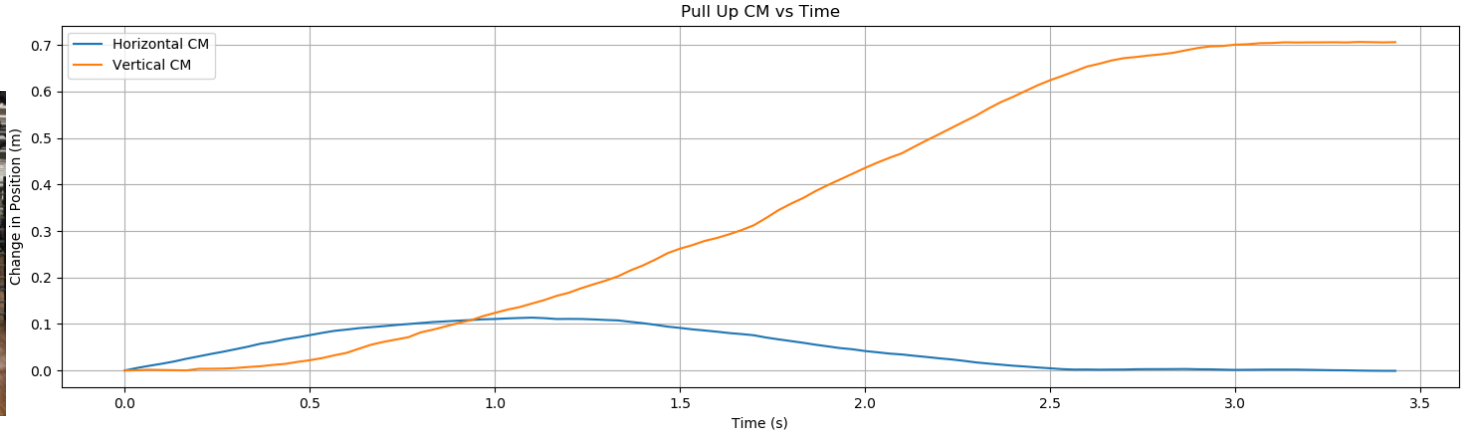
Distribution of Mechanical Demand

Wrist: |NJM| = 46.8 Nm => 19%
Elbow: |NJM| = 44.39 Nm => 18%
Shoulder: |NJM| = 159.18 Nm => 63%

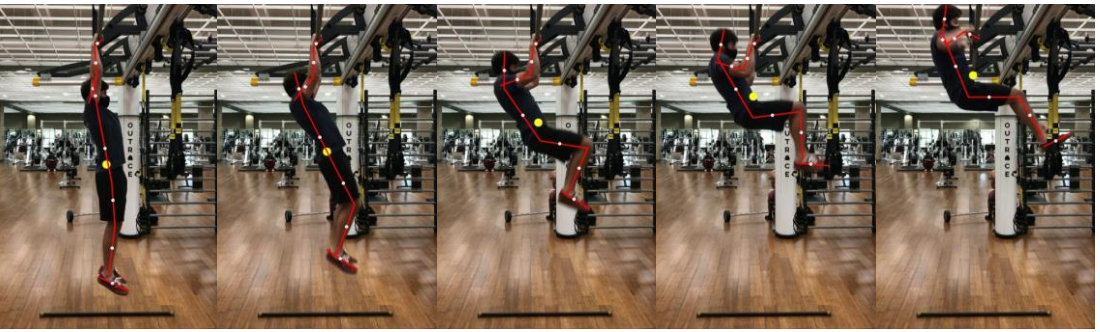
Task Comparison: Position

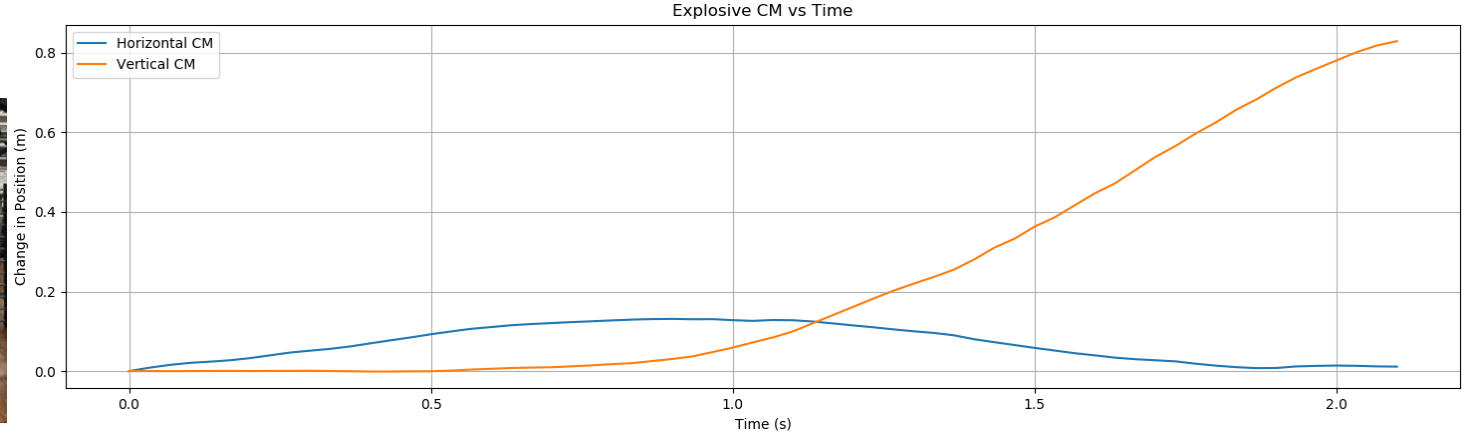
Pull Up



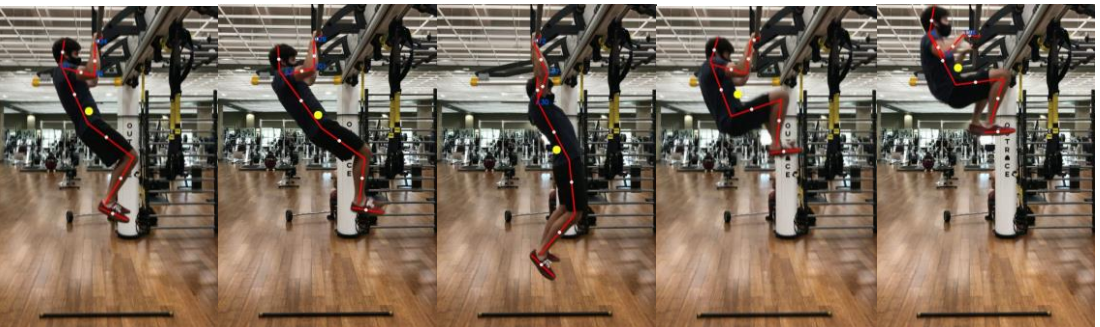


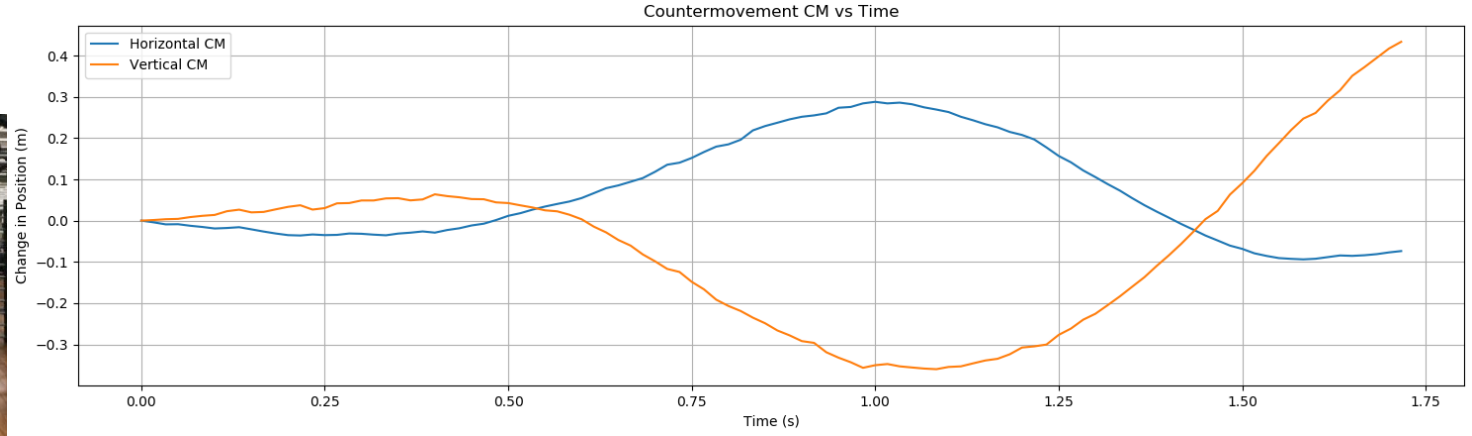
Explosive Pull Up





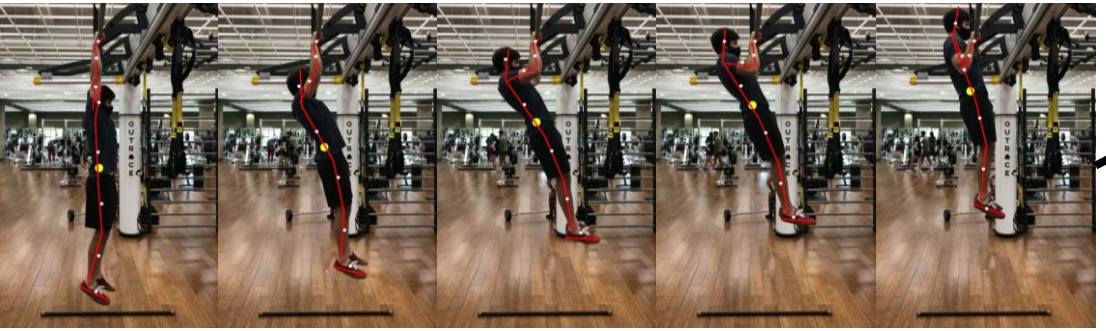
Countermovement Pull Up

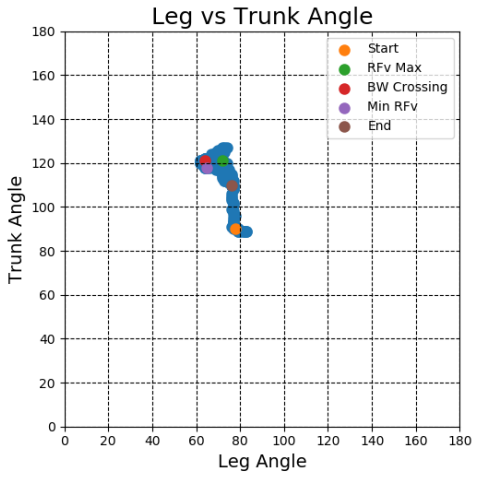


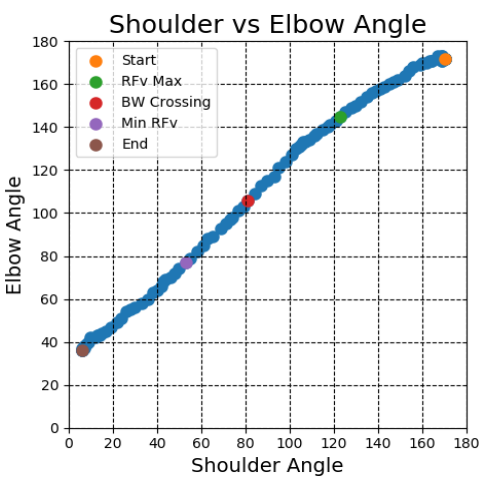


Task Comparison: Angles

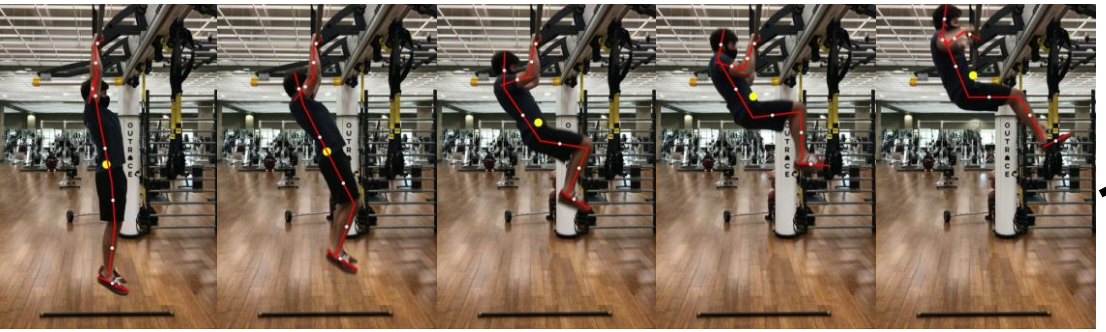
Pull Up

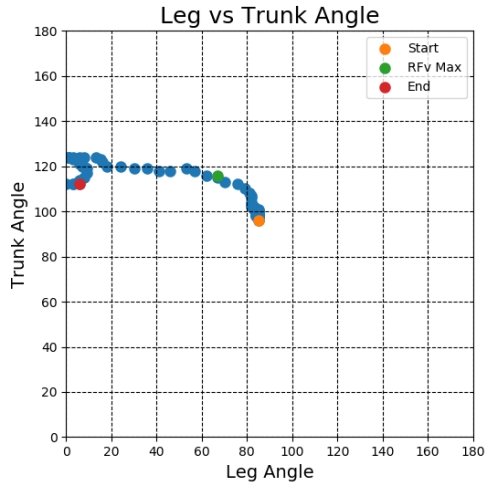


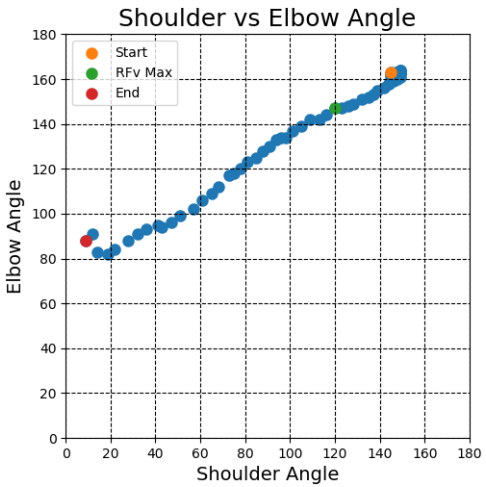




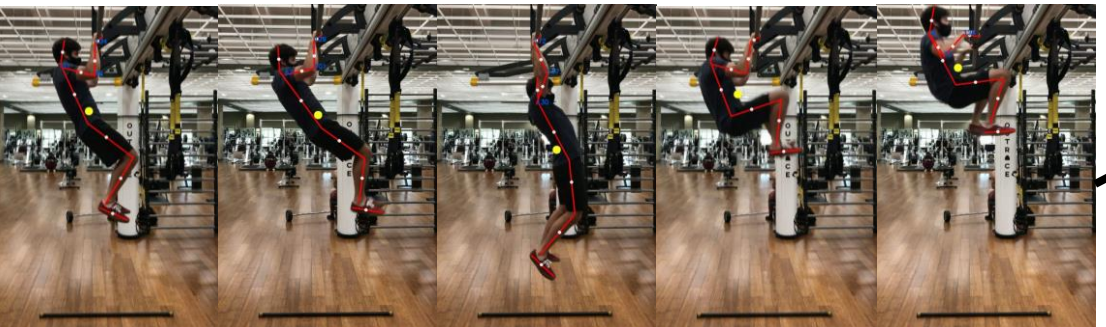
Explosive Pull Up

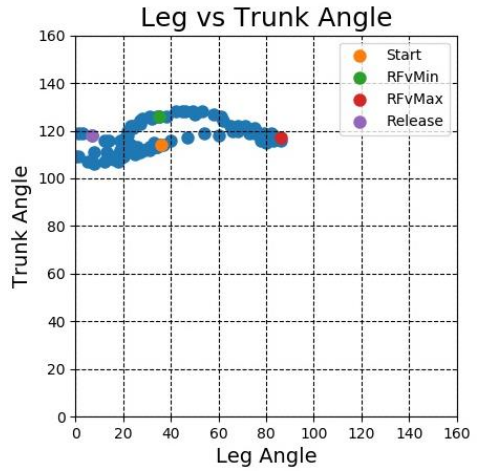


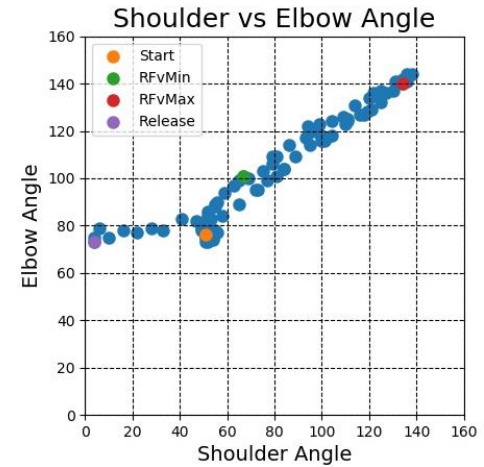




Countermovement Pull Up



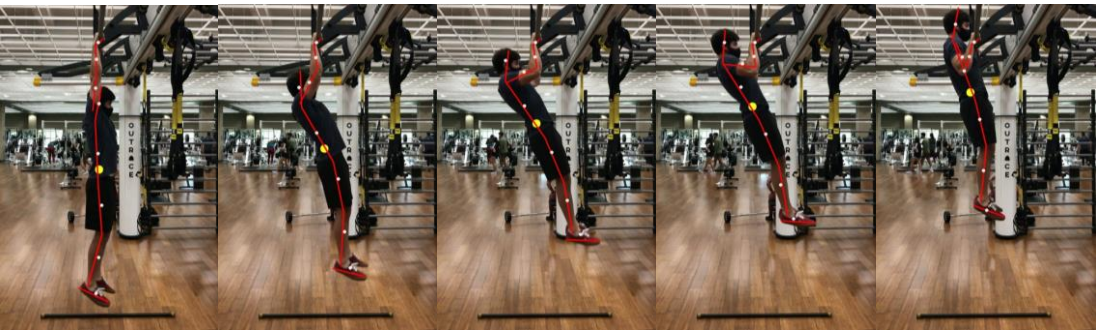




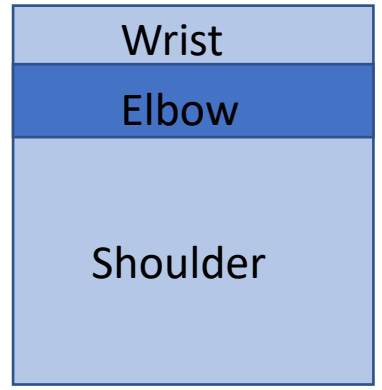
Task Comparison: Joint Kinetics

Distribution of Mechanical Demand

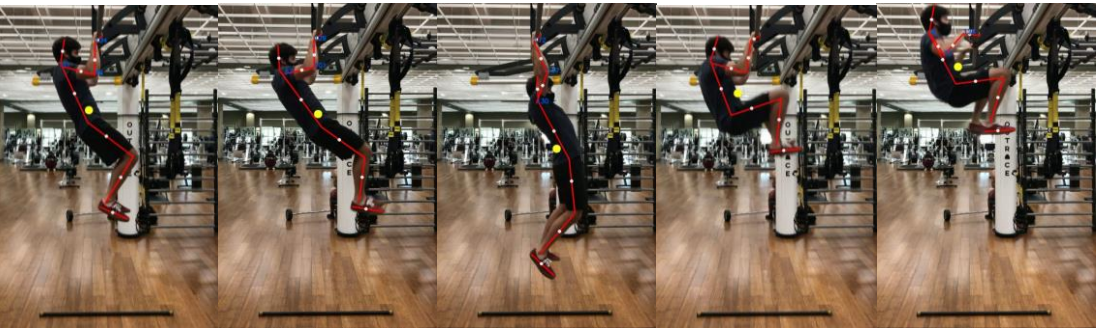
Pull Up



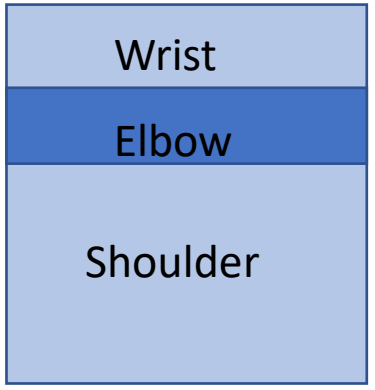
$|NJM_{wrist}|$ = 21 Nm [17%]
$|NJM_{elbow}|$ = 17.27 Nm [13%]
$|NJM_{shoulder}|$ = 91.83 Nm [70%]



Countermovement Pull Up



$|NJM_{wrist}|$ = 46.86 Nm [19%]
$|NJM_{elbow}|$ = 44.39 Nm [18%]
$|NJM_{shoulder}|$ = 159.18 Nm [63%]



Task Comparison Observations:

- Position/Time:
  - Position vs Time is very similar for both pull up and explosive pull up and for primary phase of countermovement pull up
  - Slope of position-curve for primary phase of countermovement is much steeper than regular pull up and explosive pull up
  - Greater slope means greater velocity which implies higher peak reaction force in the vertical
- Angle/Angle
  - Angle/Angle diagrams also relate speed of movement. Proximity of points being relatively closer than others implies slower movement
  - Angle/Angle diagrams are relatively similar in shape though reflecting similar movement
- Joint Kinetics
  - In terms of absolute value of NJM's the values go Pull Up < Exp Pull Up < CM Pull Up
  - The shoulder experiences the most demanding moments for each task

Solutions and Conclusions

- Quicker pull up implies greater reaction force
  - Peak reaction force for each task goes from greatest to least: countermovement pull up, explosive pull up, regular pull up
  - Velocity (slope of position/time curve) reflects this peak reaction force order
  - Follows from research of using 1 rep max for weighted pull ups to reflect velocity of unweighted pull up (Sanchez-Moreno, M., Rodriguez-Rosell, D., Pareja-Blanco, F., Mora-Custodio, R., & Gonzalez-Badillo, J. J. (2017). Movement Velocity as Indicator of Relative Intensity and Level of Effort Attained During the Set in Pull-Up Exercise. *International Journal of Sports Physiology and Performance,12*(10), 1378-1384. doi:10.1123/ijspp.2016-0791)
- Task relates to goal of movement
  - If slow and controlled movement is desired => regular pull up is optimal
  - If vertical velocity and time constrained movement is desired => explosive pull up is optimal
  - If maximized vertical velocity is desired => countermovement pull up is optimal
- Results reflected by stakeholders and interviewed
  - Jordan Dawson, Climbing Coach: immense value in having higher vertical velocity
  - Maddy Morris, Climbing Coach: explosive pull up from stationary valued for speed climbing