Biomechanics Every Golf Instructor Should Know

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Olympic Training Center
Chula Vista, CA

LPGA Summit 2015

My Background

- Australian Gymnast
- Olympian
  - 1976, 1980
- Biomechanist
  - PhD from ASU
  - Dissertation Research
  - Golf Swing
- US Olympic Committee
  - Olympic Training Center Chula Vista, CA
  - Senior Sport Technologist
  - Golf, Track and Field, Trampoline, Swimming
- AMM Co-Founder
  - Co-developer of AMM 3D
- TPI Biomechanics Advisor
  - Co-developed TPI 3D
- "The 3D Guy"

Chula Vista
Olympic Training Center

Golf in the Olympics

Current World Rankings 10/7/15

MEN

- Jordan Spieth USA
- Jason Day AUS
- Rory McIlroy IRE
- Bubba Watson USA
- Rickie Fowler USA

WOMEN

- Inbee Park KOR
- Lydia Ko NZL
- Stacy Lewis USA
- So Yeon Ryu KOR
- Lexi Thompson USA

TEAM USA

USA GOLF™

Rio2016™

Biomechanics

- The study of human motion using the principles of math, geometry, physics, engineering, and anatomy
- In sports we use biomechanics to provide rational to why we teach specific techniques
- Two goals of biomechanics
  - Rapidly Improve Performance
  - Reduce Injury Risk
- Biomechanics can also help with equipment design

Kinematics and Kinetics

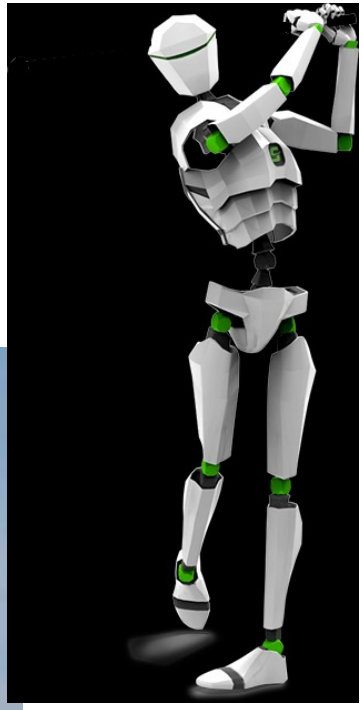
- Kinematics: Motion
  - Motion of objects without concern for the forces or torques that produce the motion.
- Kinetics: Forces
  - Forces and interactions that produce or affect motion.
  - Includes internal and external forces.

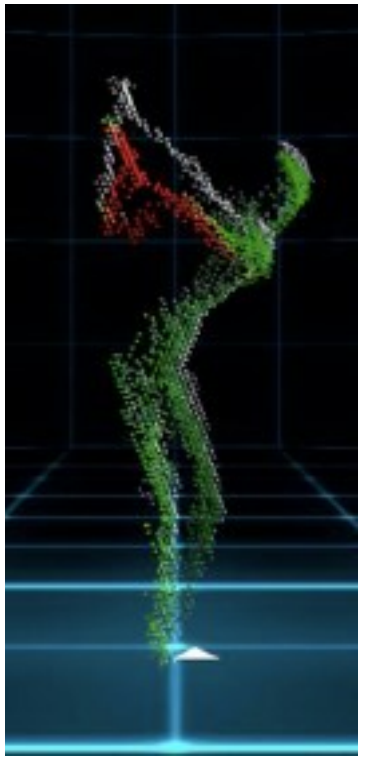
To study something we need to measure it!

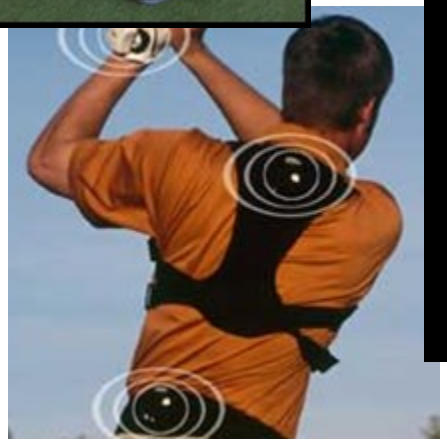
How Do We Measure Three-Dimensional Motion?

Motion Analysis Systems

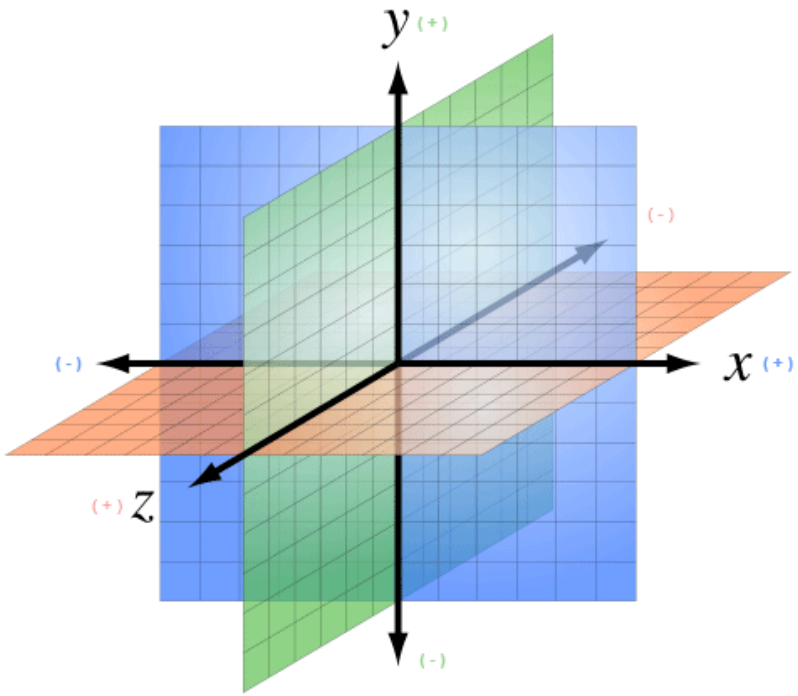
- Optical
  - Gears
  - Qualysis
  - Vicon
  - MAC
  - MATT
- Inertial
  - K-Vest
  - mySwing
- Electromagnetic
  - AMM3D w TPI 3D
- Markerless
  - SwingGuru

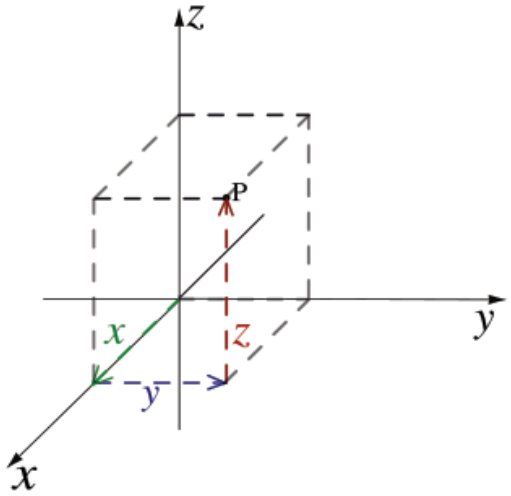


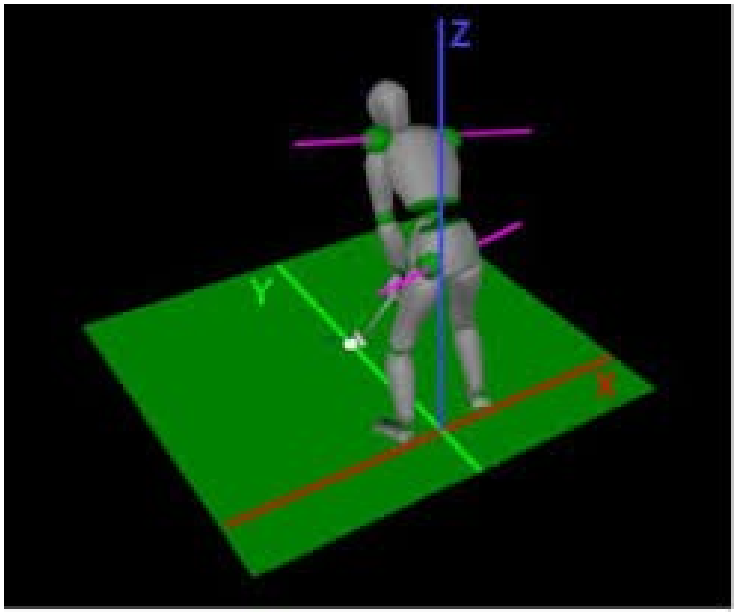




Measurement in 3-Dimensions

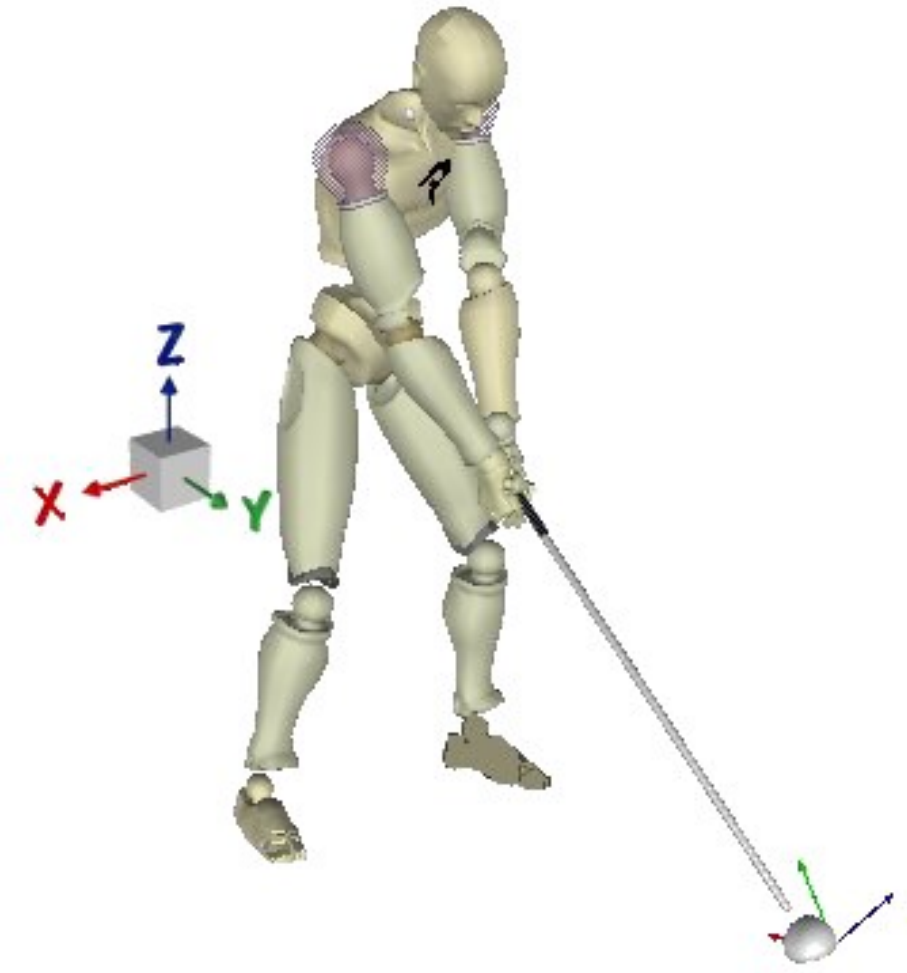




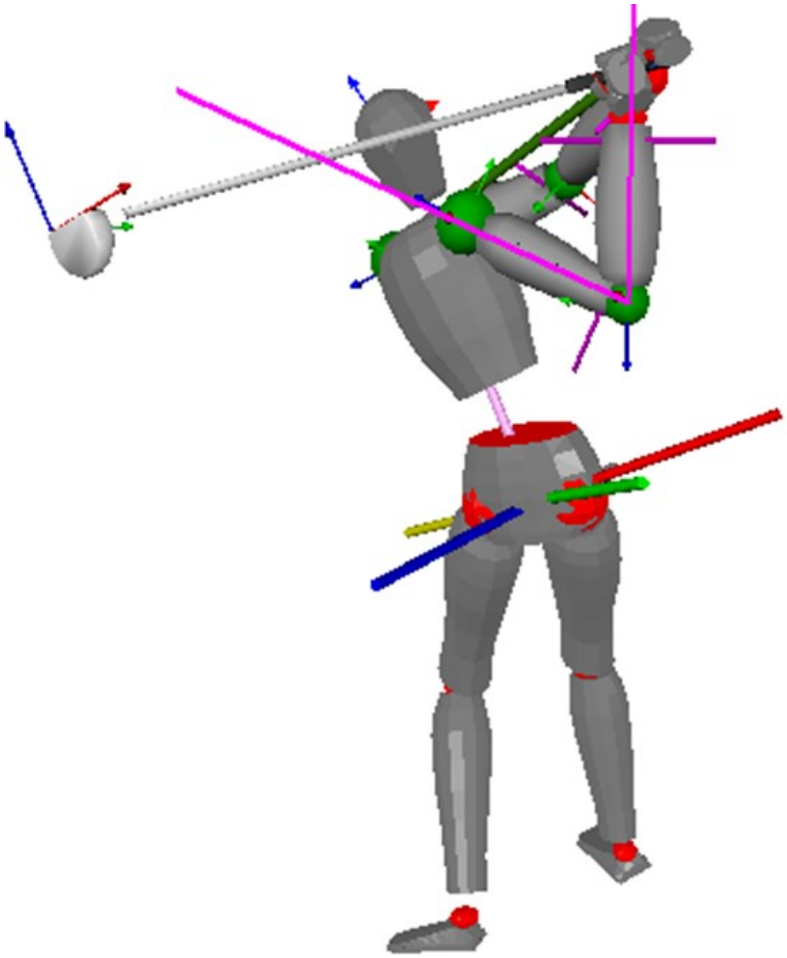


3D Coordinate System
OR
Reference Frame

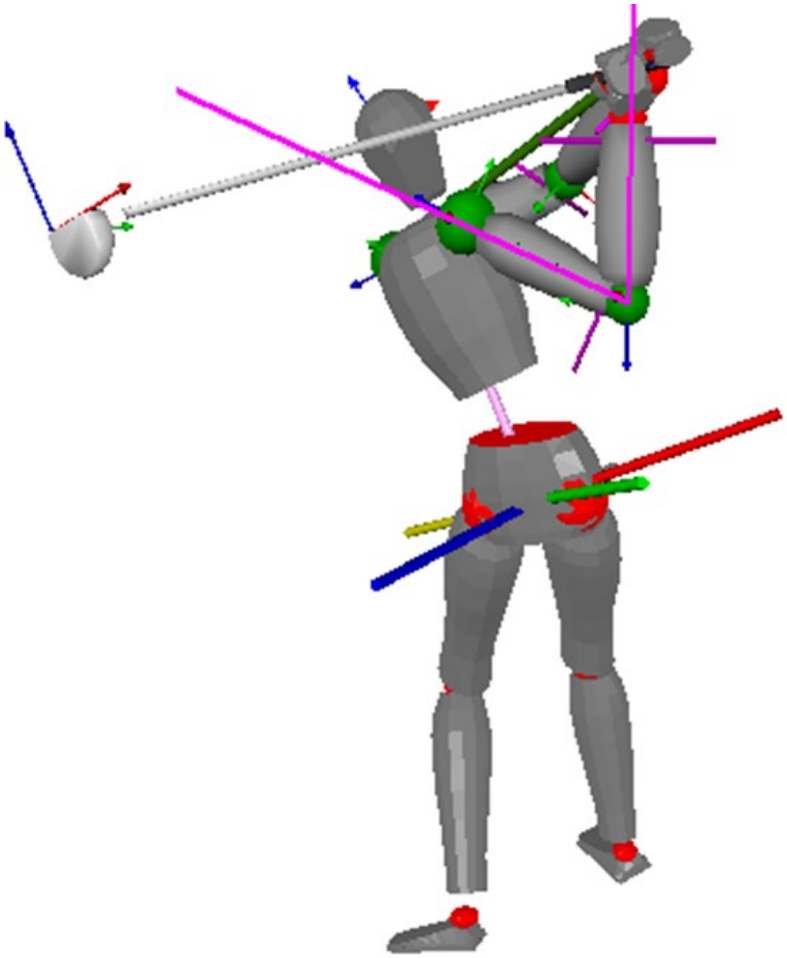
Global Reference Frame



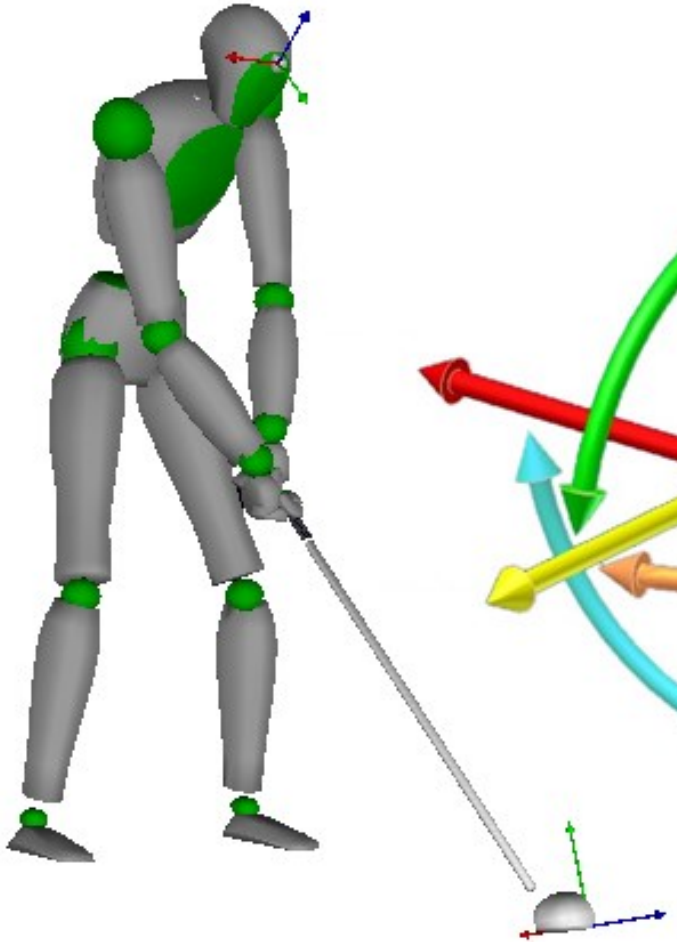
Local Reference Frames



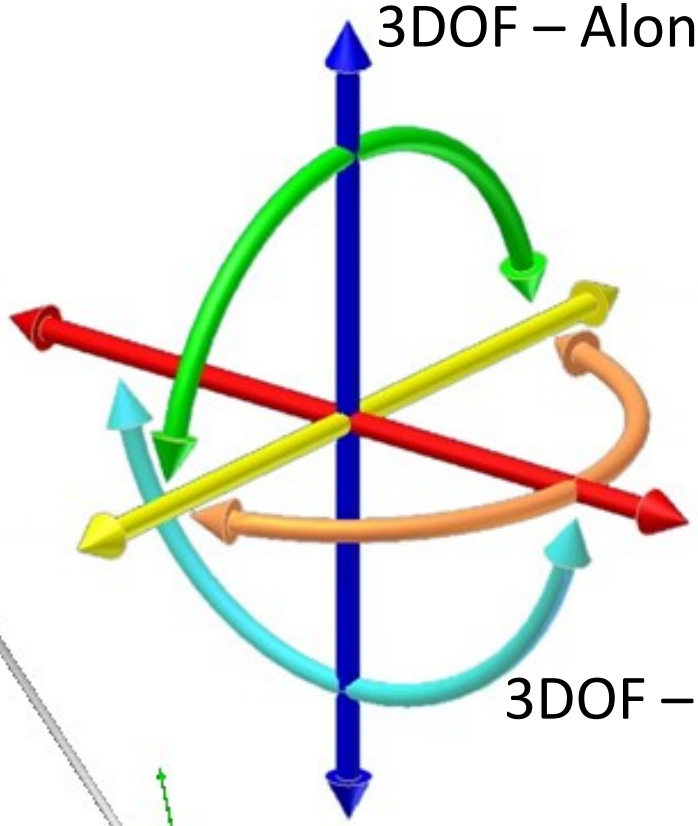
Local Reference Frames



Six-Degrees-of-Freedom

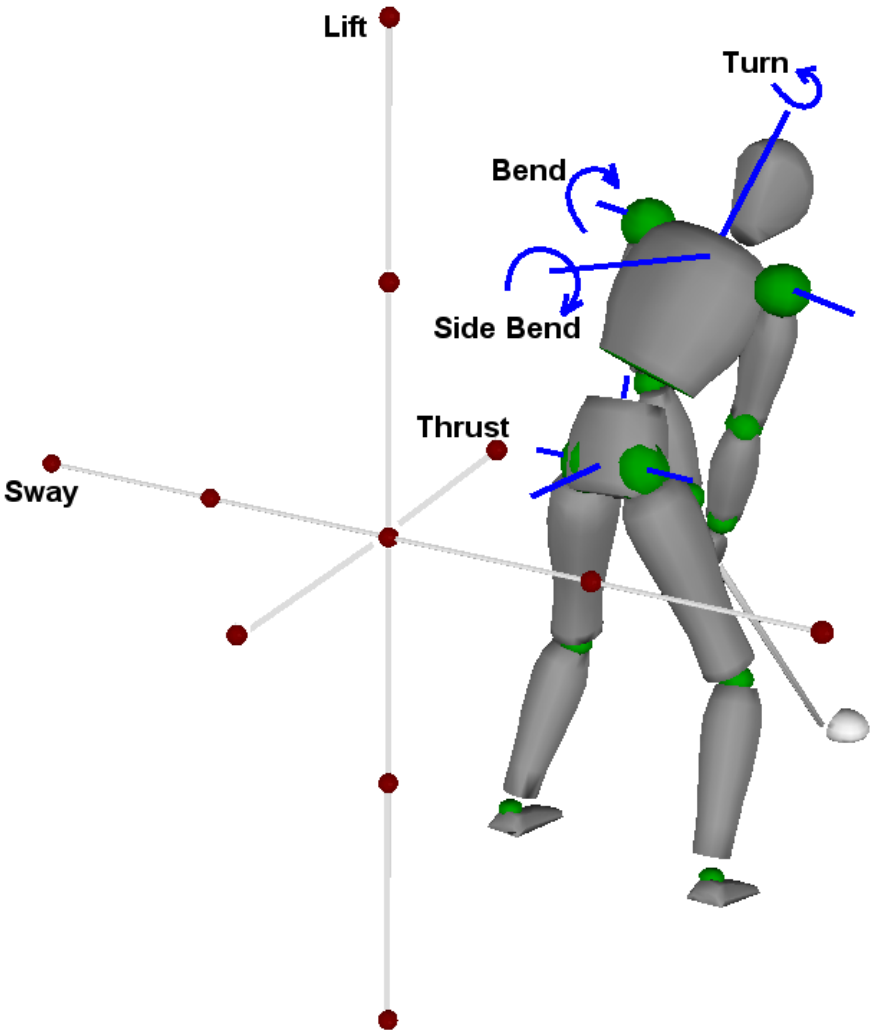


3DOF – Along Each Axis



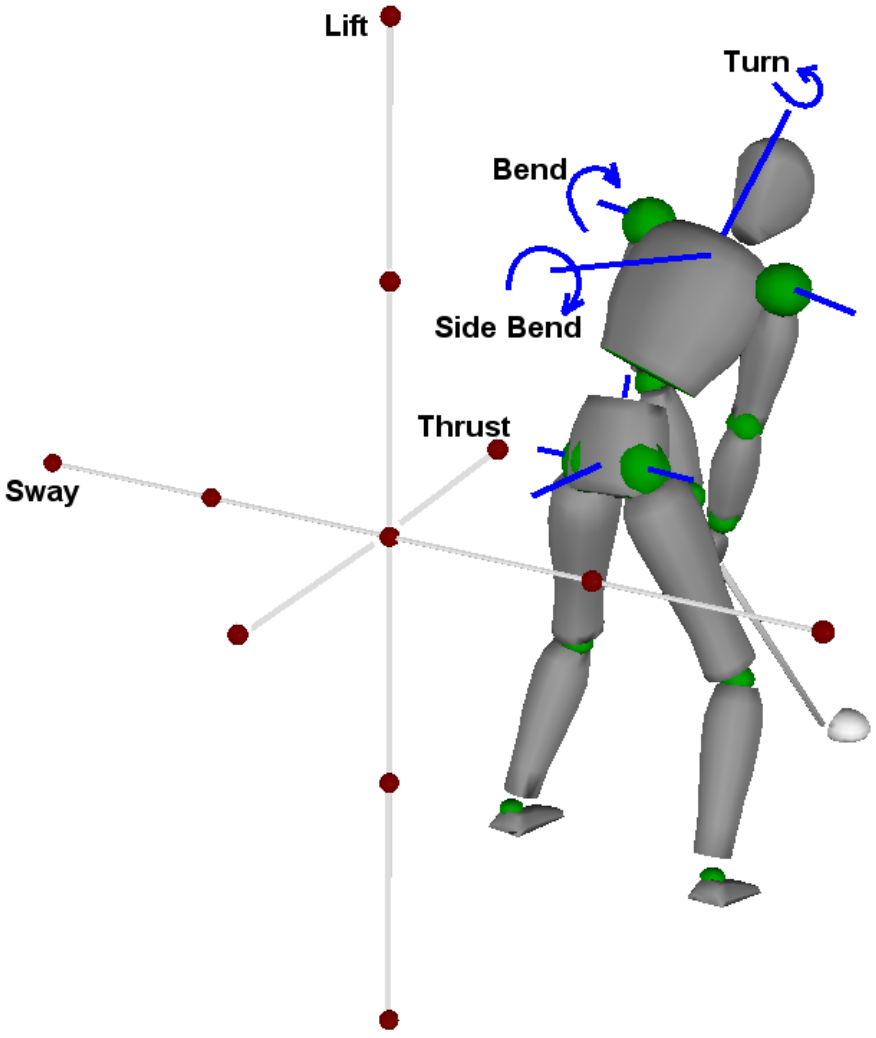
3DOF – Around Each Axis

3DOF – Linear Position



- Movement Along an Axis
  - Sway
    - Along the Side-to-Side Axis
    - Toward-Away
  - Thrust
    - Along the Front-Back Axis
    - Forward-Backward
  - Lift
    - Along the Up-Down Axis
    - Up-Down
  - POSITION
    - Inches, Feet, Meters

3DOF – Angular Orientation



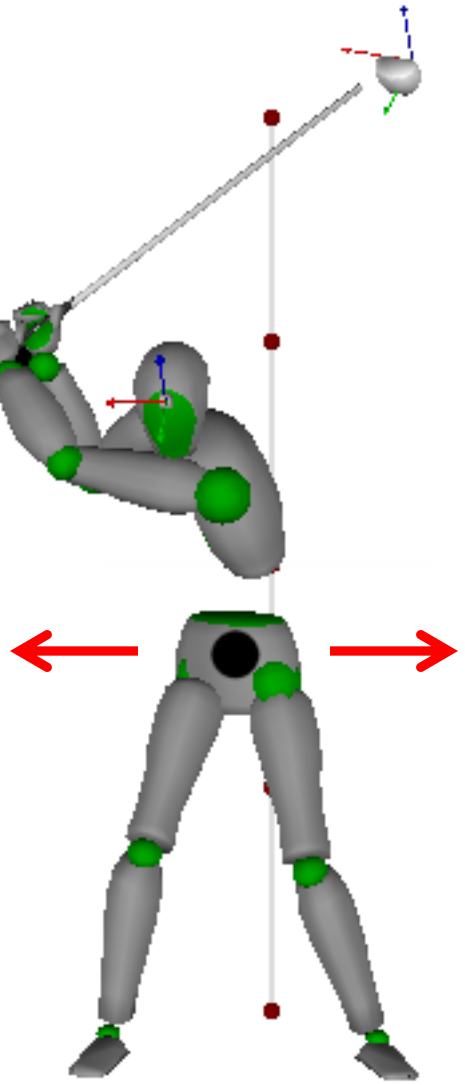
- Rotation Around an Axis
  - Bend
    - Around the Side-to-Side Axis
    - Forward-Backward
  - Side Bend
    - Around the Front-Back Axis
    - Trail-Lead
  - Turn
    - Around the Up-Down Axis
    - Open-Closed
  - ORIENTATION
    - Degrees, Radians, Revs

Why is this important for golf?

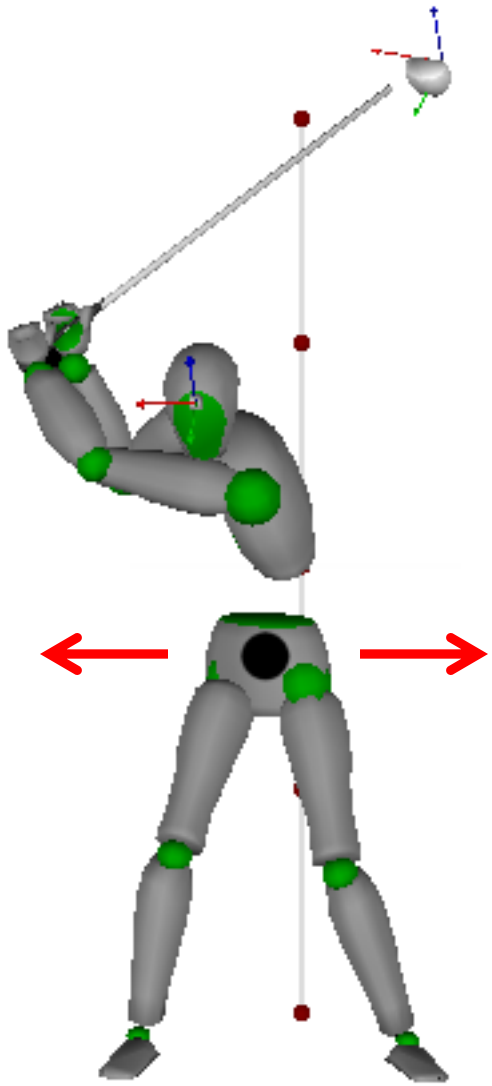
We can measure the movement in each direction
and
track the entire body motion in 3D

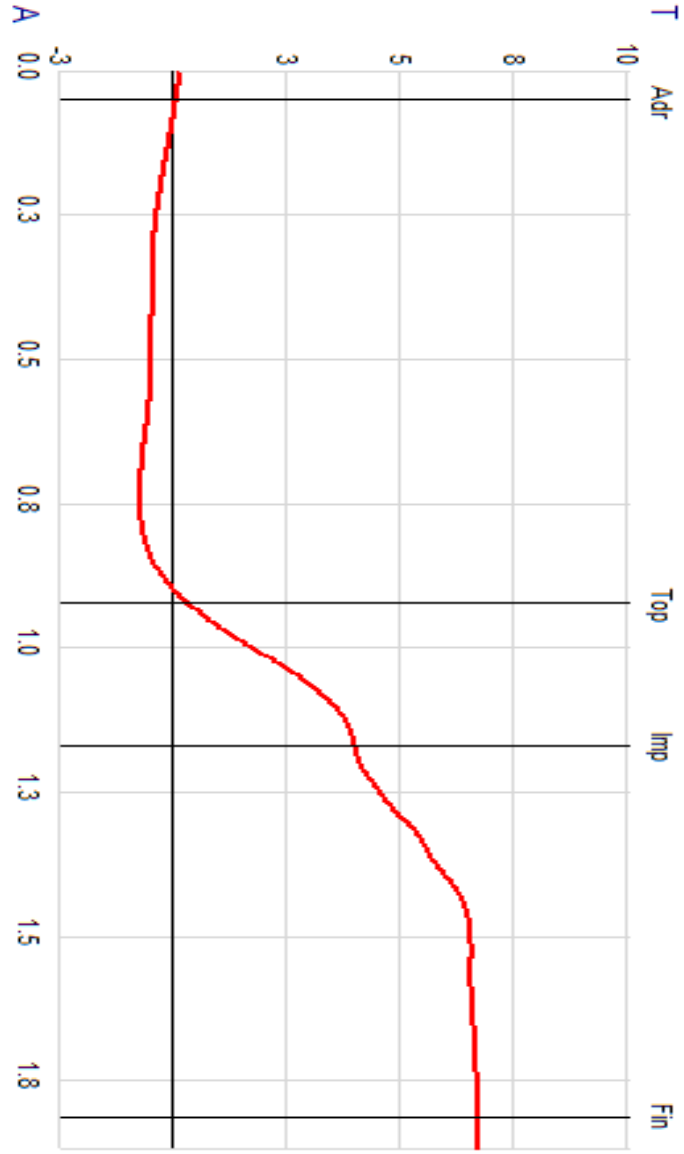
Sway

- Side to side motion of pelvis and ribcage
- Movement away from target in backswing
  - Negative on graph
- Movement toward target in downswing
  - Positive on graph
- Swing “variations”
  - Sway in backswing
  - Hang back in downswing
  - Slide in downswing



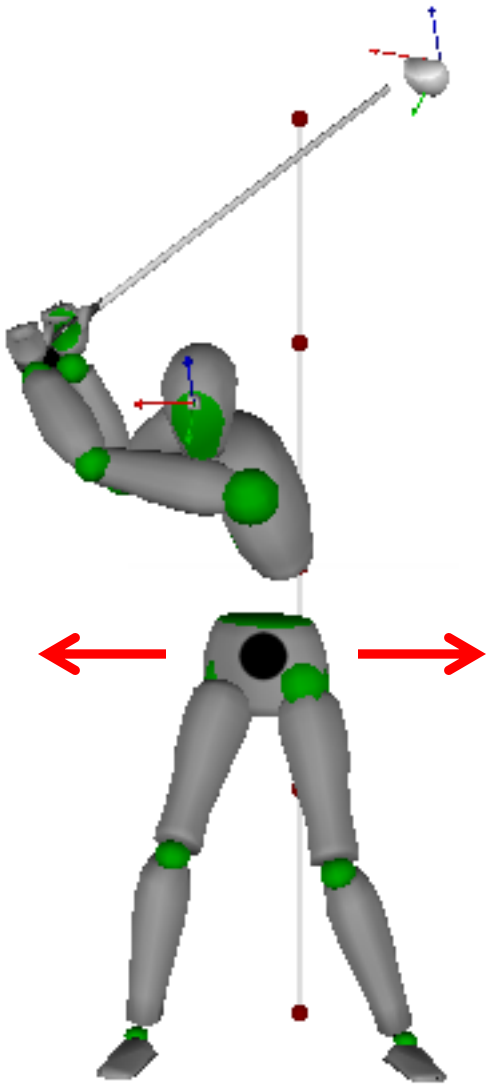
Pelvis Sway

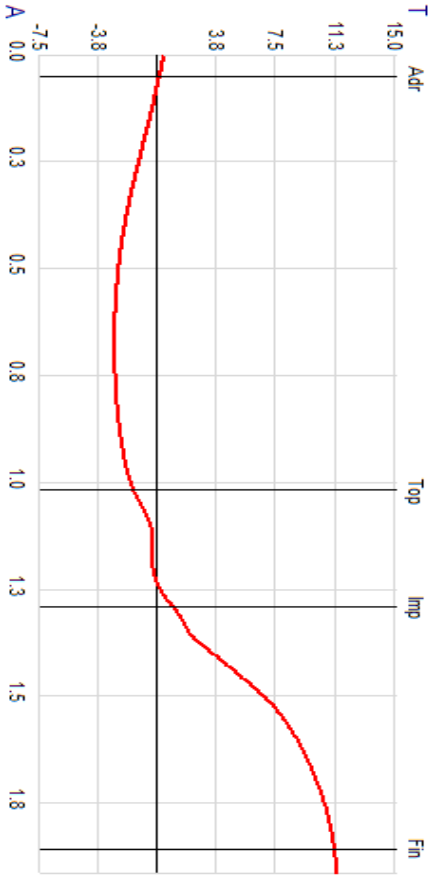




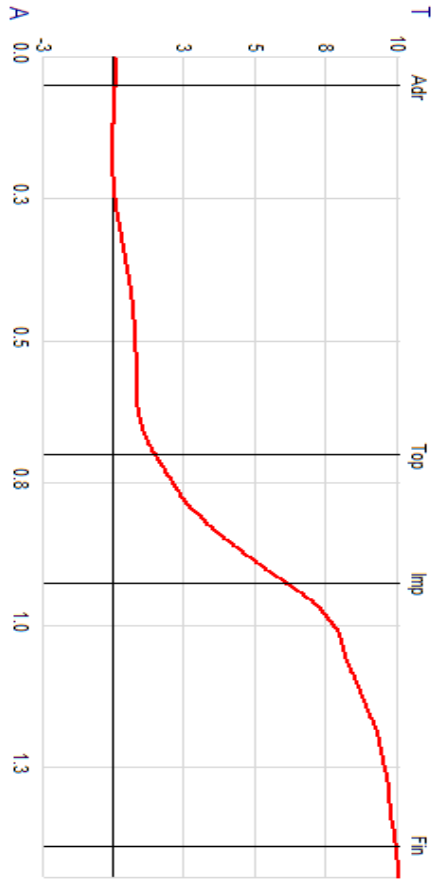
Load Right
Move Left
Stabilize

Pelvis Sway – More Examples





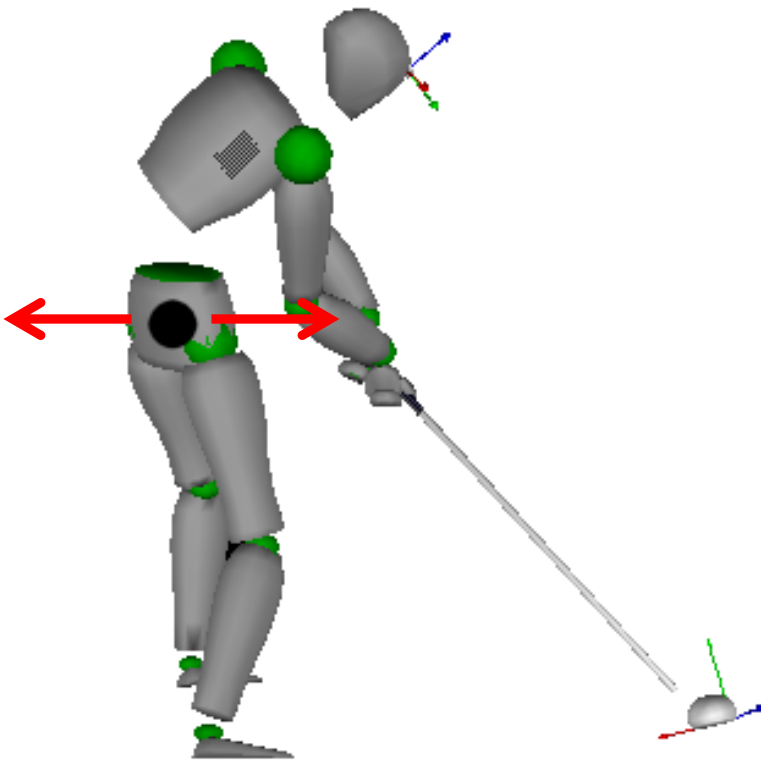
Sway Right
Move Left
Hang Back



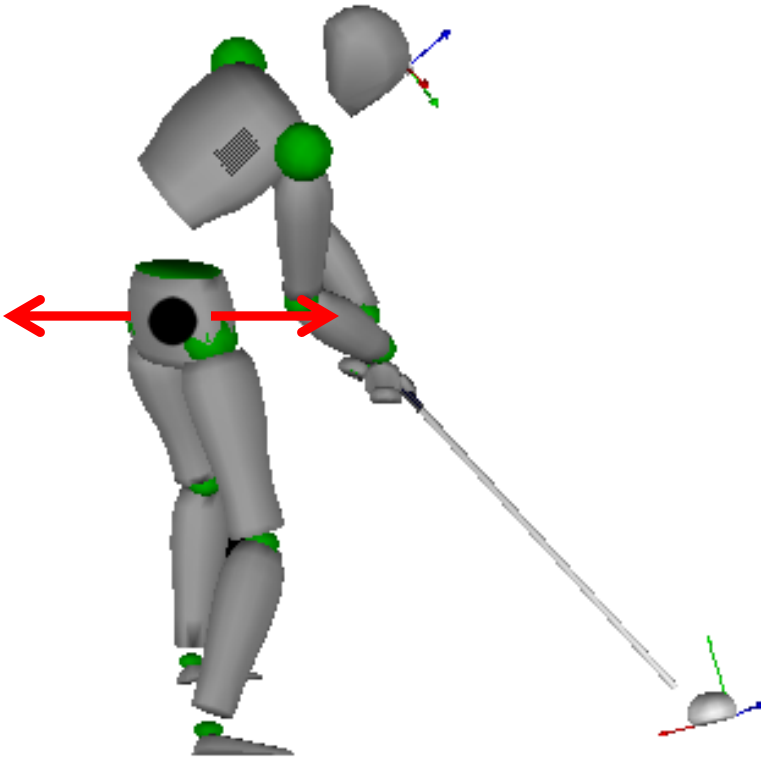
Lean Left
Move Left
Slide

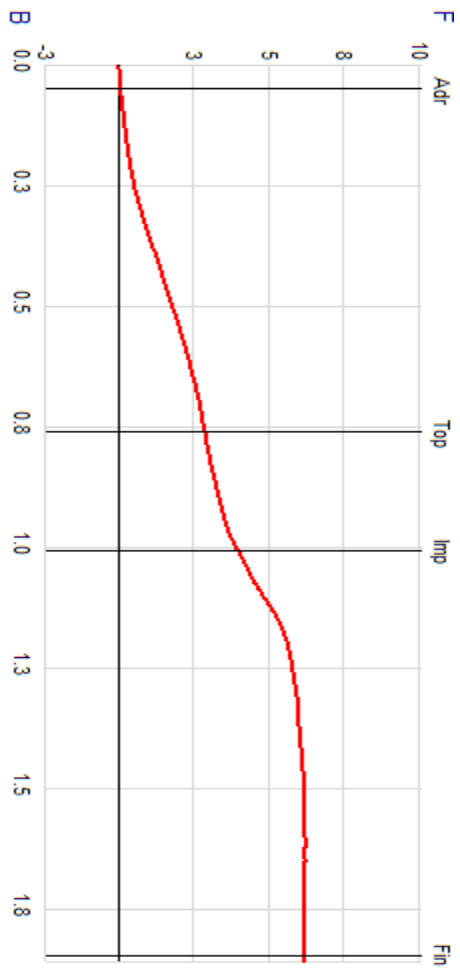
Thrust

- Motion of pelvis or ribcage towards the ball
- Forward is positive
- Backward is negative
- Indicator of coming out of posture
- Swing “faults”
  - Standing up at top of backswing
  - Early extension in downswing

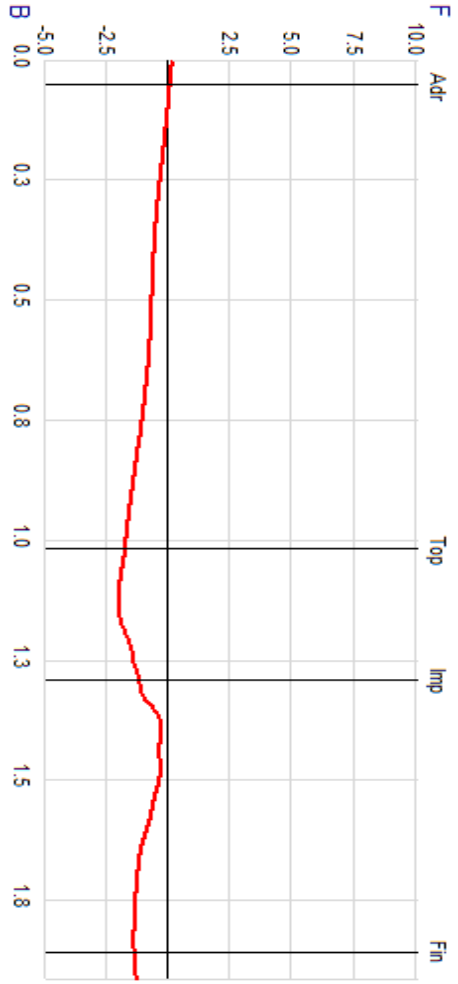


Pelvis Thrust





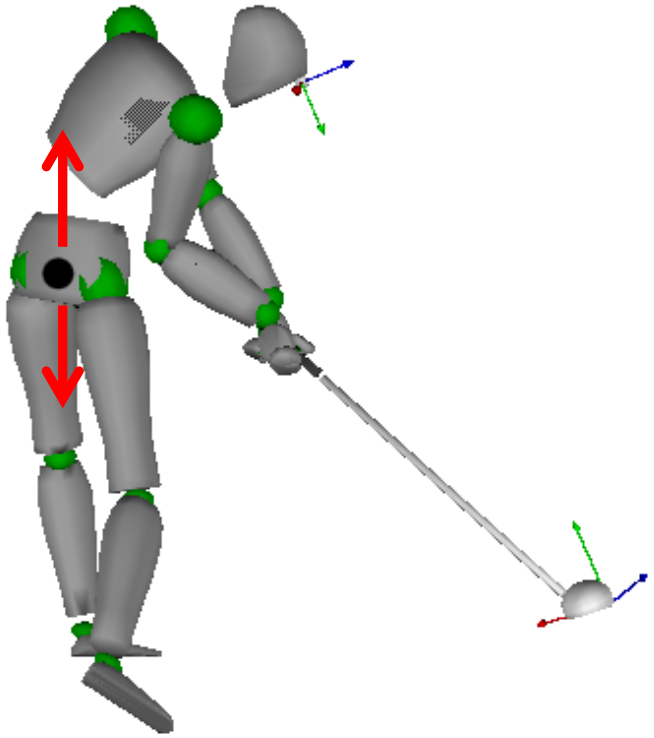
Thrust Forward



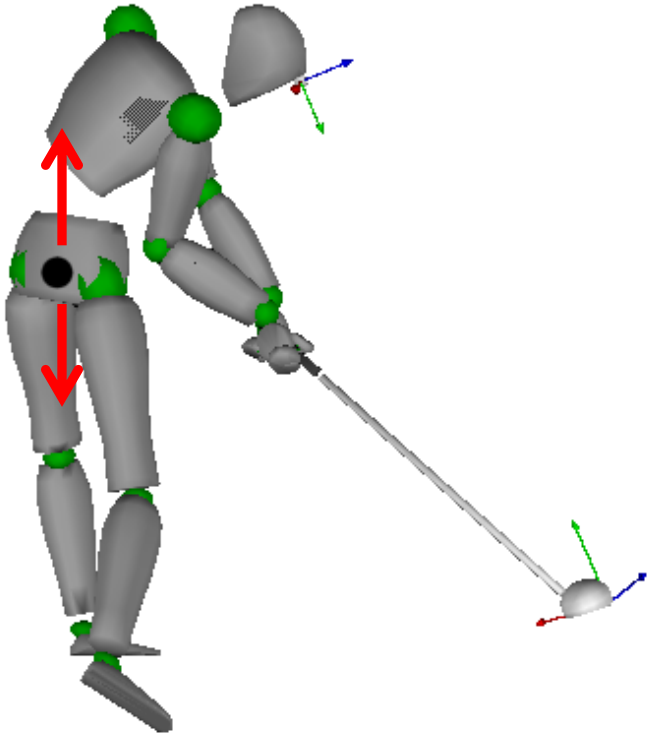
Sit Back

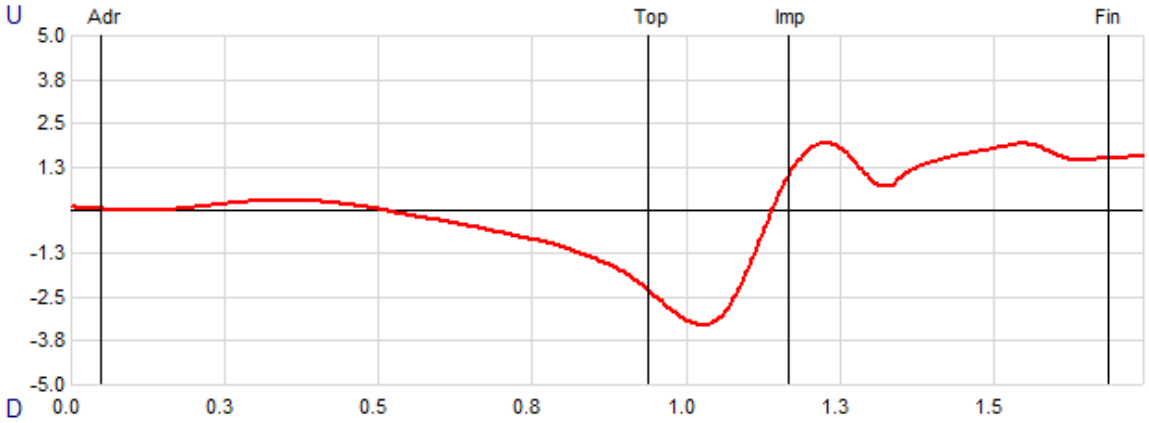
Lift

- Lift is motion up and down of the pelvis and ribcage
- Lift is positive
- Drop is negative
- Optimal motion
  - Drop early in downswing
  - Lift before impact
- Typical fault
  - Drop with no lift near impact

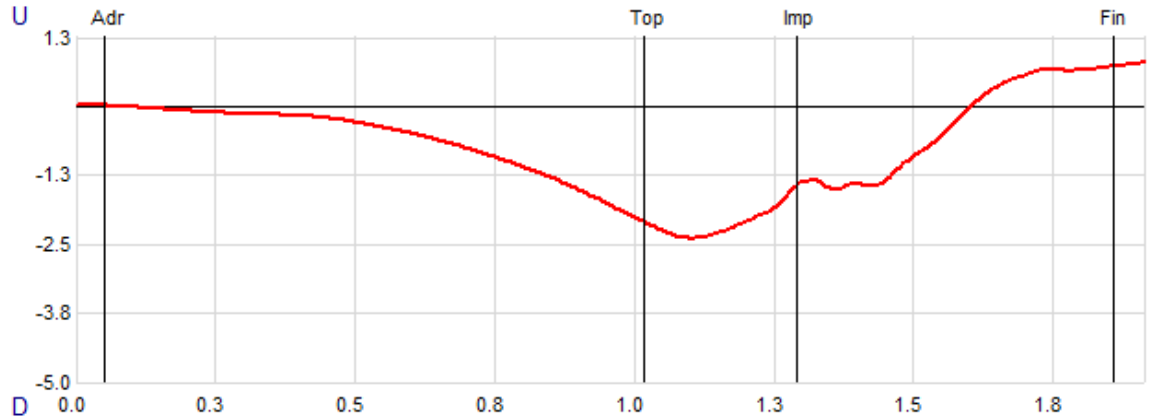


Pelvis Lift





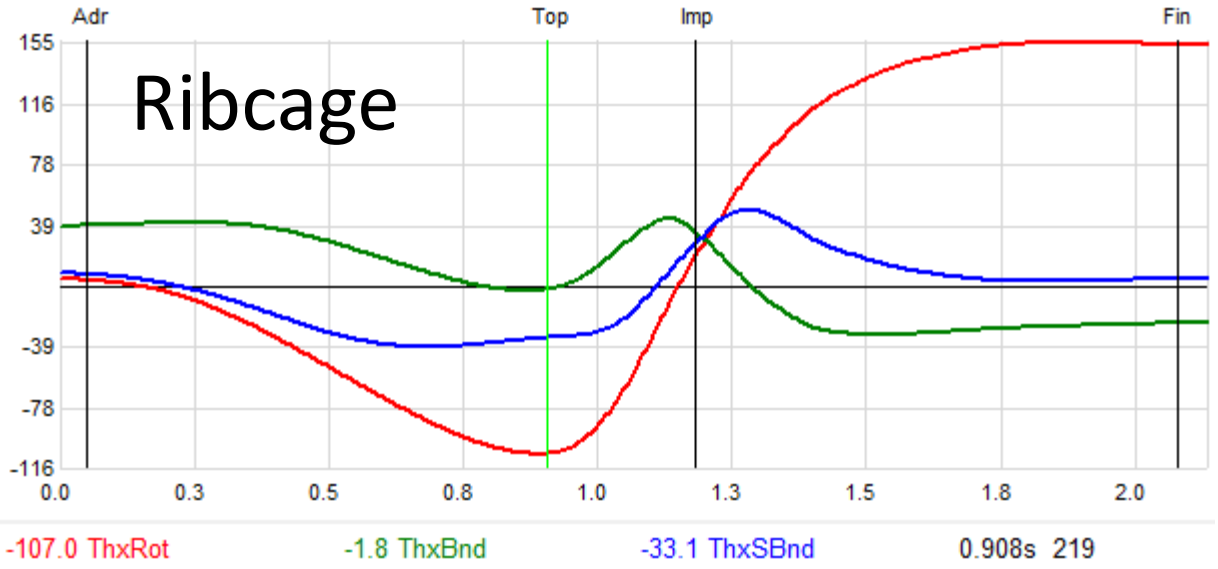
Drop then Lift

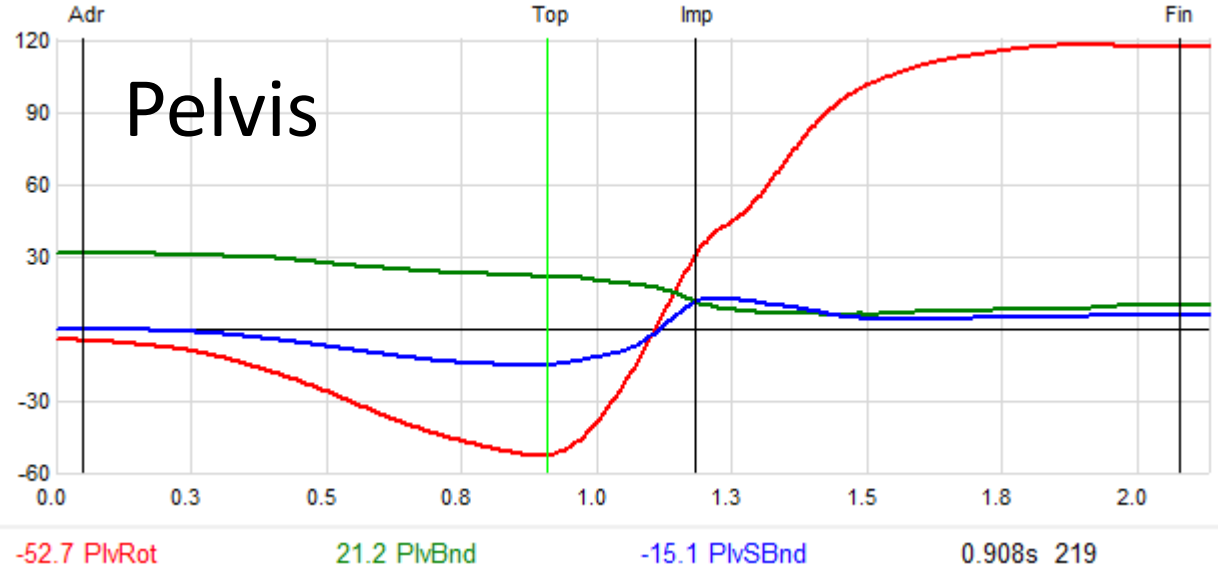


Drop and Stay Down until Finish

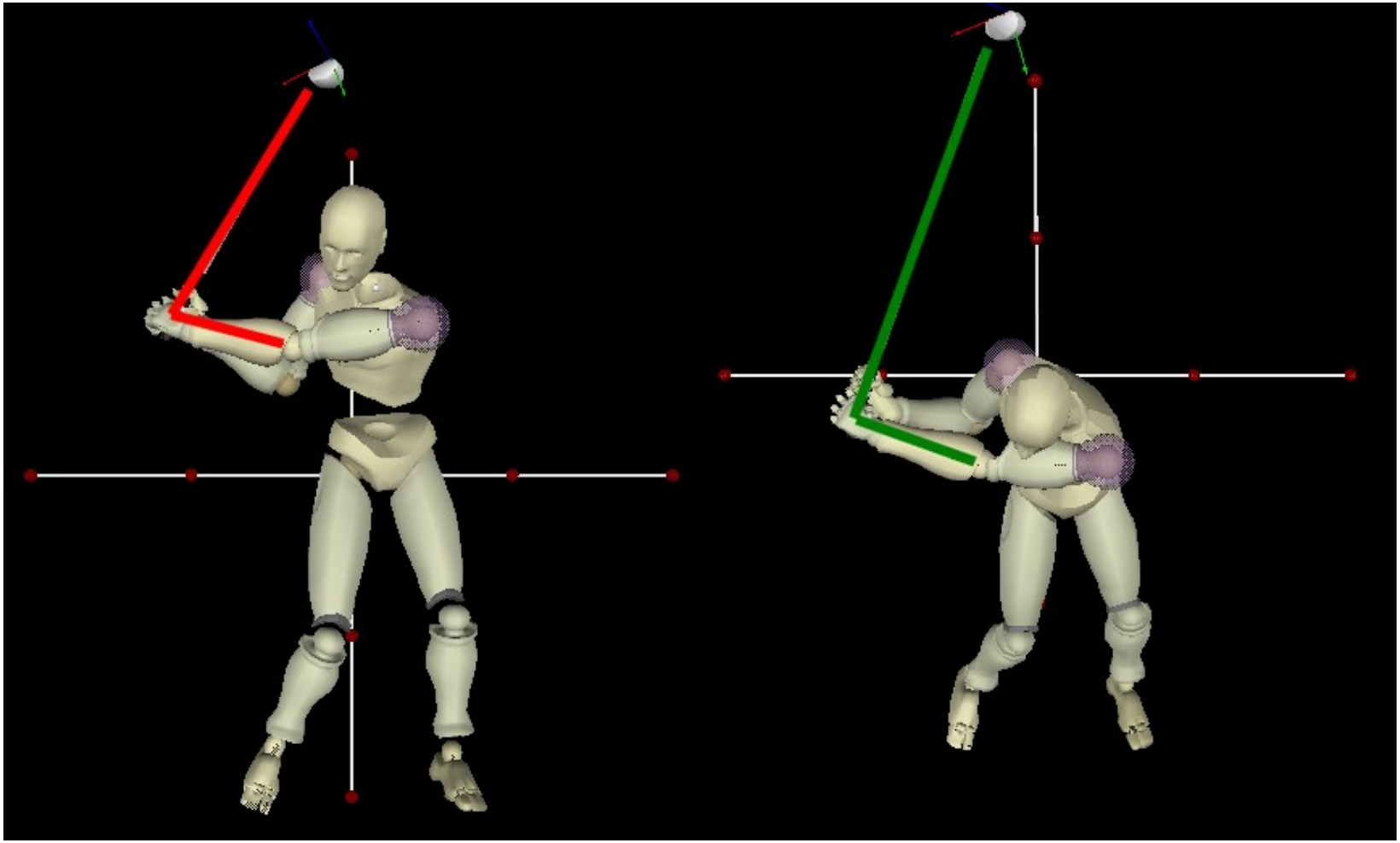
3DOF Body Angles

- Turn
- Bend
- Side Bend





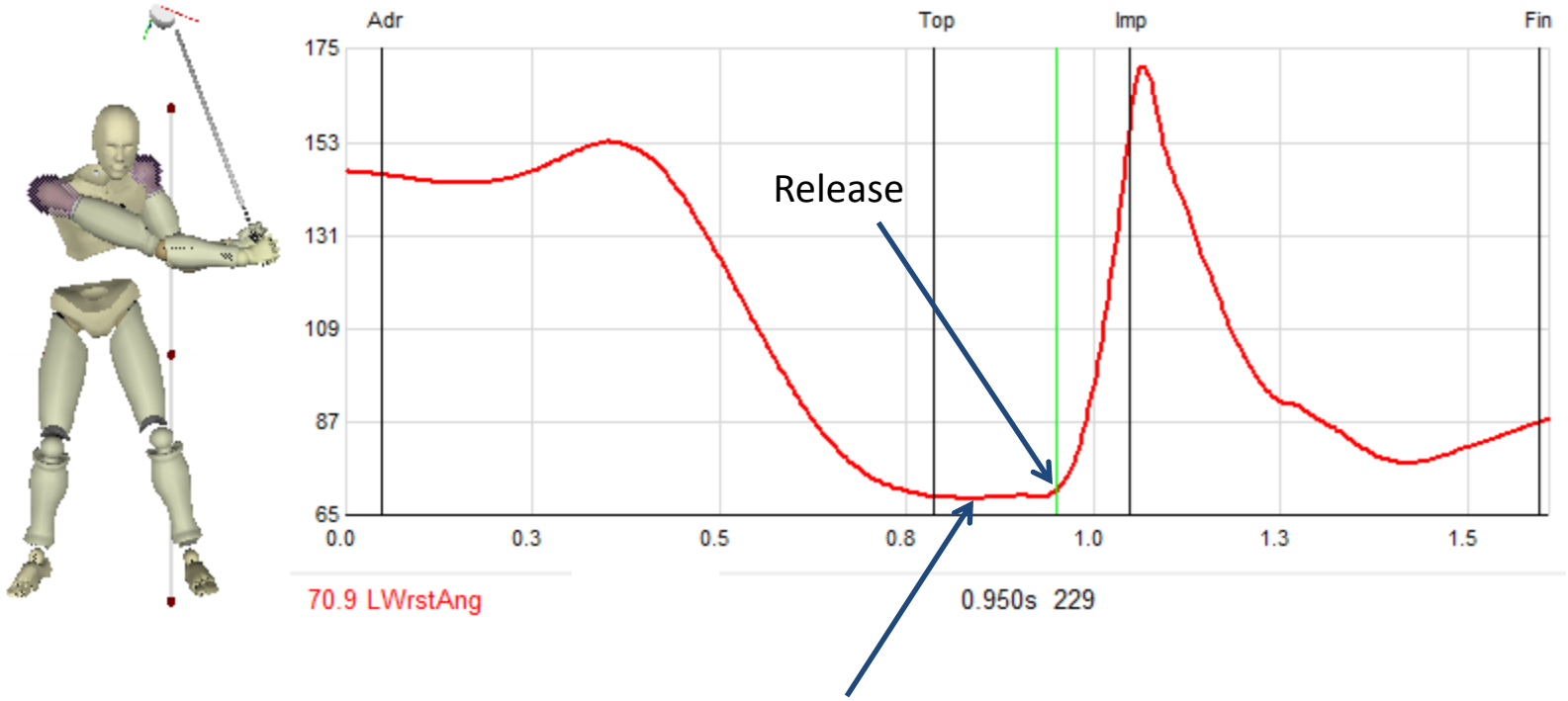
Wrist Set Angle in 3D



Wrong way to measure it

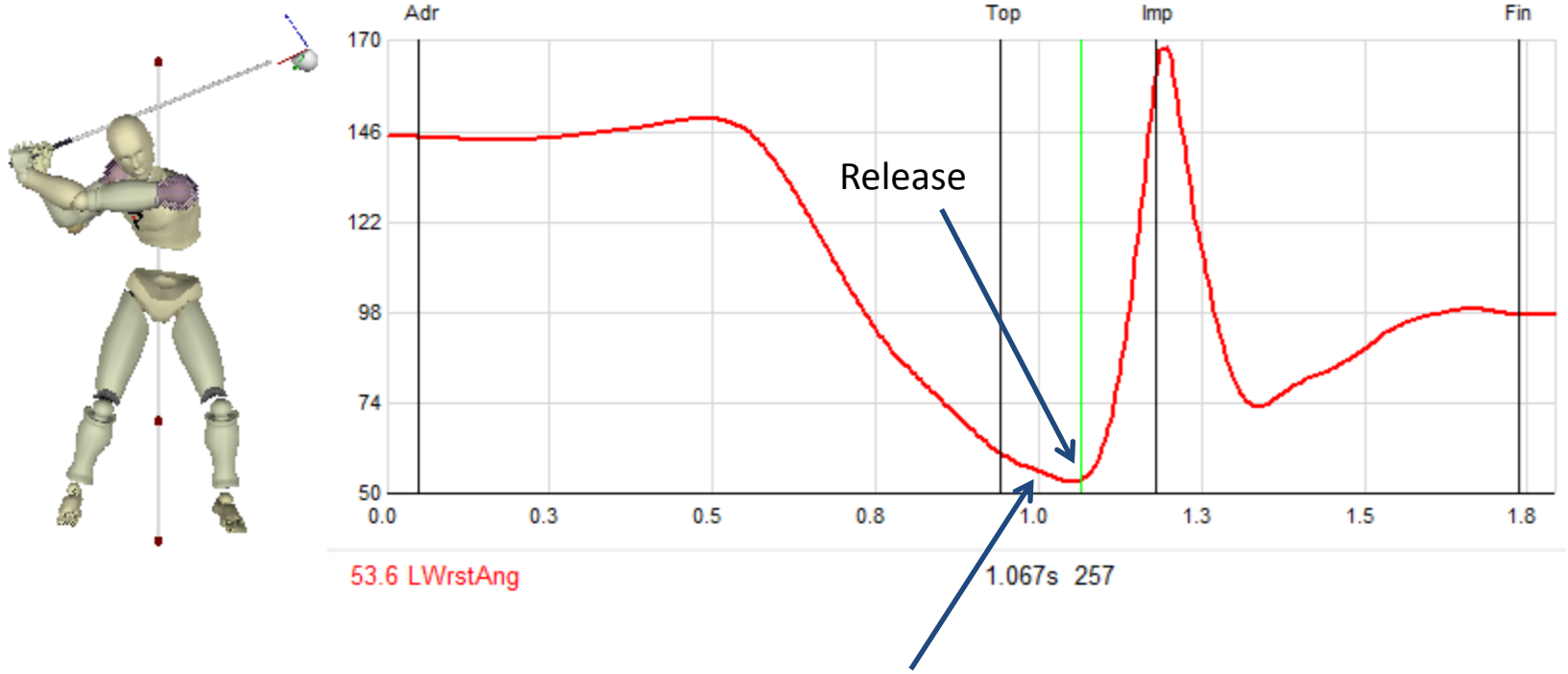
Correct way to measure it

Lead Wrist – Fixed Set Angle



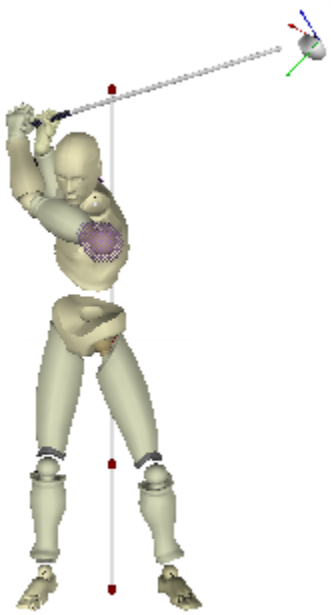
Wrist angle remains constant until release occurs

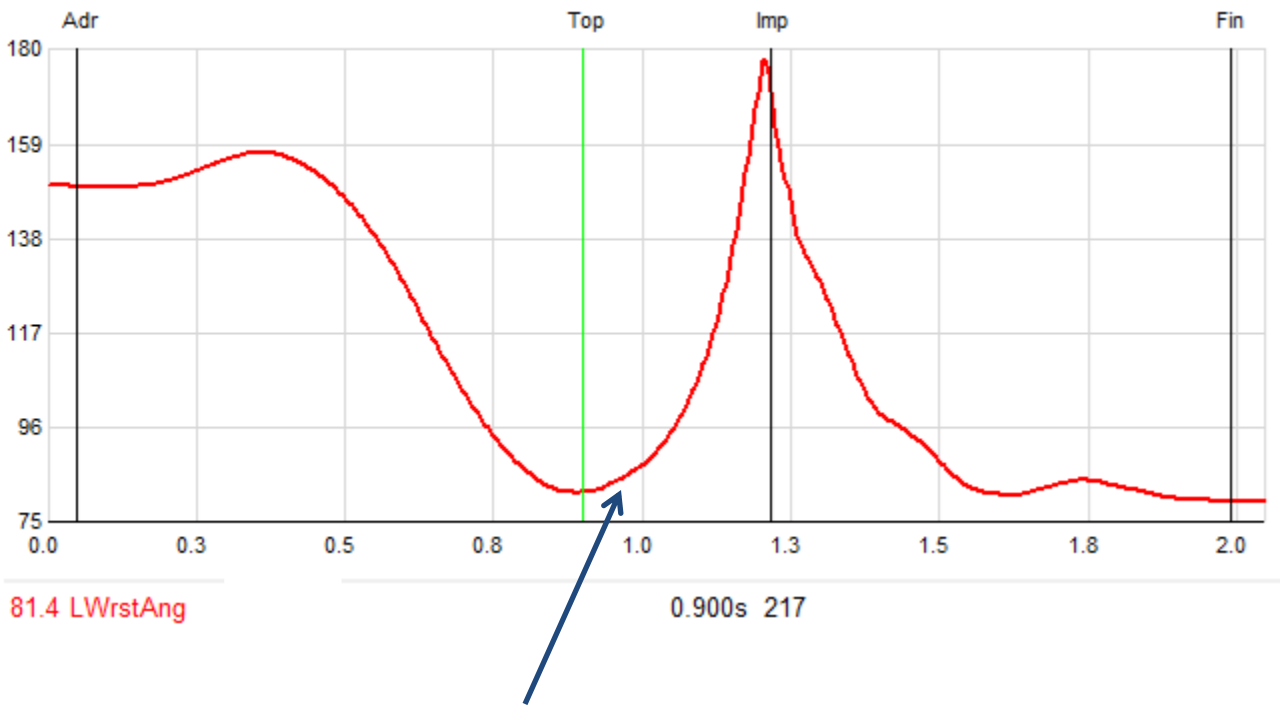
Lead Wrist – Downswing Loading



Wrist angle decreases until release occurs

Lead Wrist - Casting

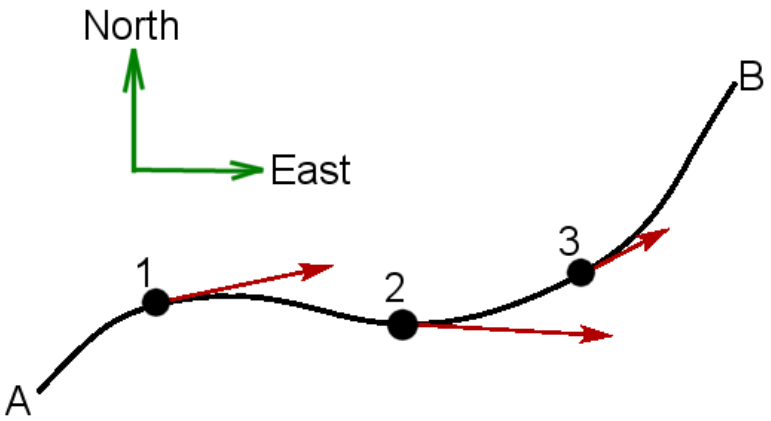




Wrist angle continuously increases during the downswing
Typical of a novice player

Linear Speed and Velocity

- Linear Speed
  - How fast you are moving in a straight line
  - Rate of change of distance
  - Speed = Distance / Time
- Linear Velocity
  - How fast and in what direction
  - Speed in a certain direction
- Average Speed
  - Total Distance / Total Time
- mph, ft/s, m/s

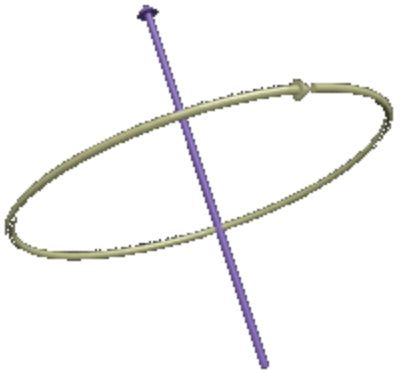


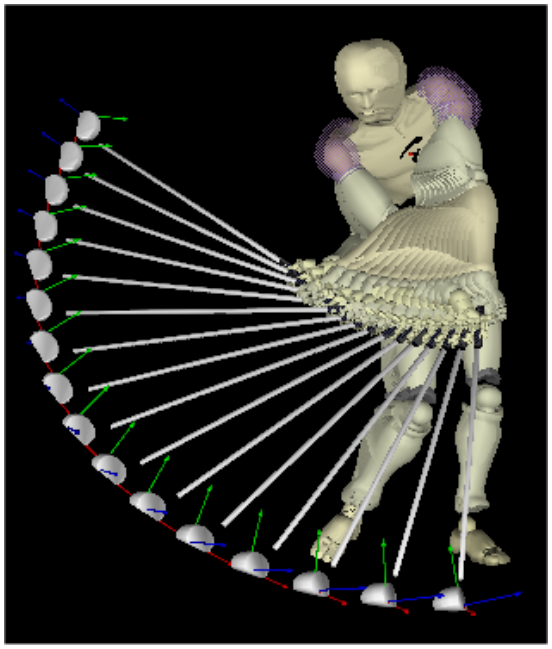
- A car is traveling from A to B
- Examples of Velocity
  1. 83 mph NE
  2. 70 mph SE
  3. 50 mph NE
- Example of Average Speed
  - The trip from A to B was 100 miles and took 2 hours
  - 100 miles / 2 hours = 50 mph

Angular Speed and Velocity

- Angular Speed
  - How fast Rotating around an axis
  - Rate of change of angle
  - Angular Speed

    = Angular Distance / Time
  - Example: 360 deg/sec
- Angular Velocity
  - Direction of axis must be defined
  - Example: 360 deg/sec around the vertical axis
  - Degrees per second





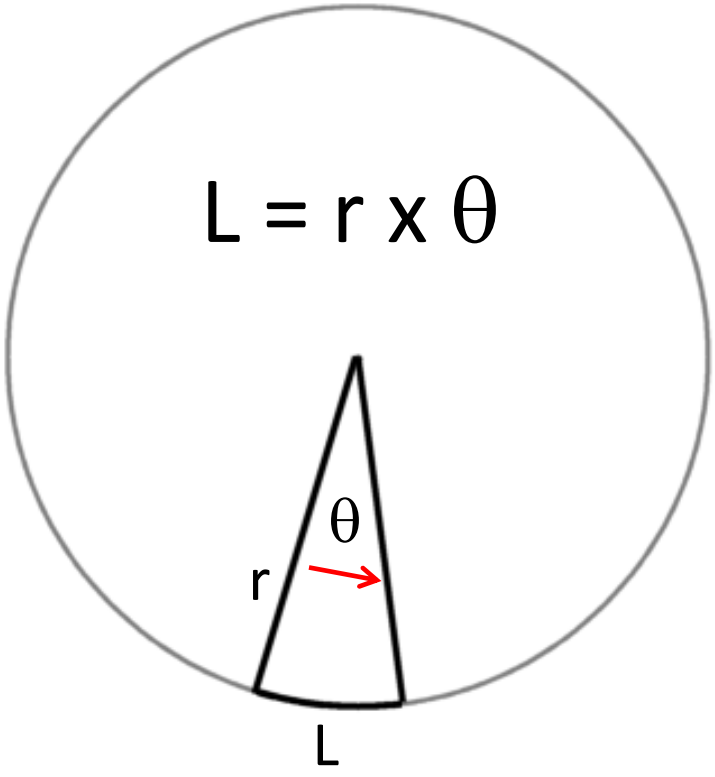
Linear and Angular Relationship

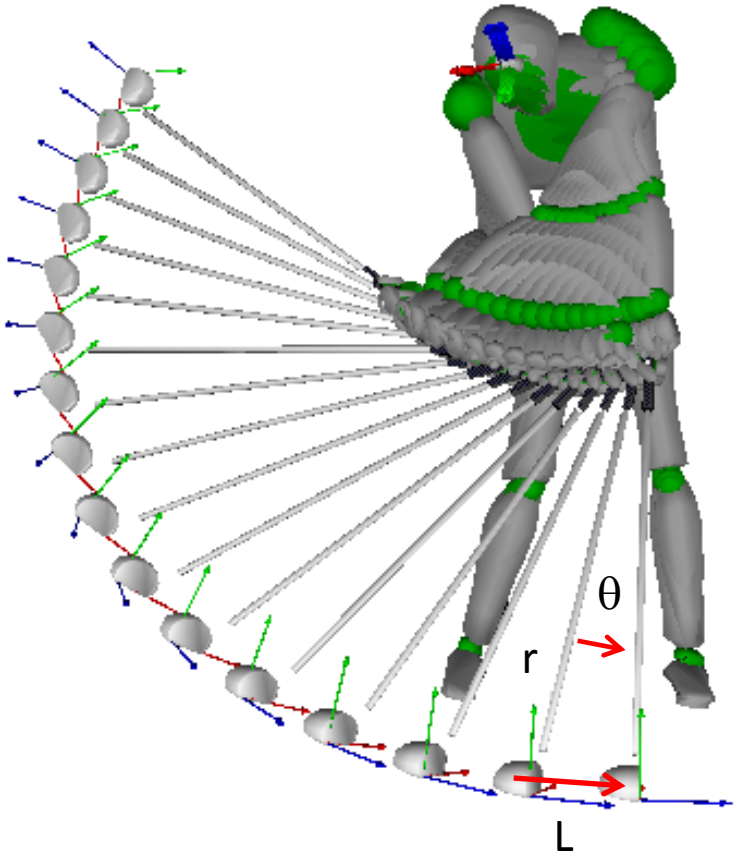
Arc Length = L

Radius = r

Angle = θ

Arc Length = Radius x Angle





Linear and Angular

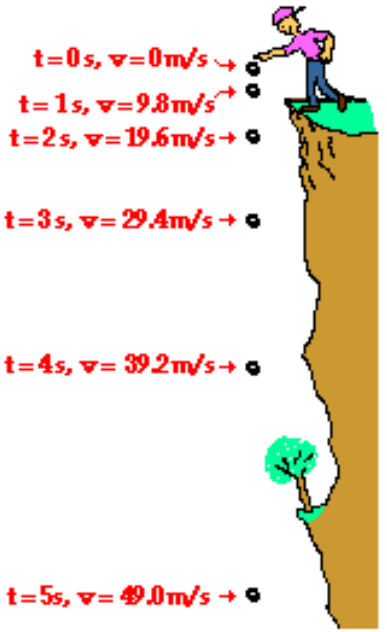
- Angular shaft speed is converted to linear clubhead speed by the length of the shaft.
- The longer the shaft the higher the club head speed for the same angular speed
- Shaft Angular speed in degrees/second
- Clubhead linear speed in feet/second or mph

Example:

- Shaft angular speed
  - 2200 d/s
- Clubhead linear speed
  - 107 mph

Acceleration and Deceleration

- Acceleration is “Speeding Up”
- Deceleration is “Slowing Down”
- Acceleration technically is
  - Rate of Change of Velocity or a = Δv / Δ t
  - A vector with both magnitude and direction
- Related to Force by Newton’s Second Law
  - Force = mass x acceleration
- Apply force in same direction as motion
  - Object will speed up
- Apply force in the opposite direction as motion
  - Object will slow down
  - Stop, and speed up in the other direction



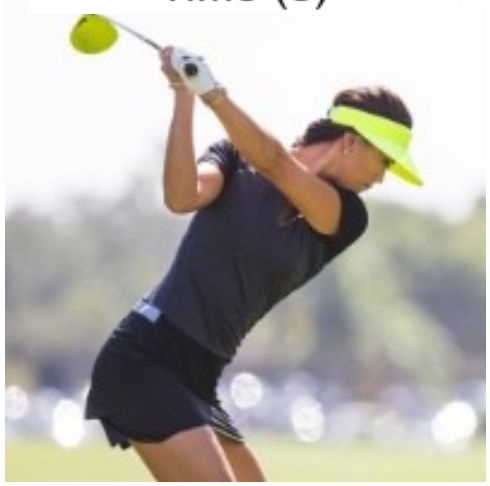
Example of Clubhead Acceleration

- Michelle Wie
- Top of Backswing = 0 mph
- Impact = 107 mph
  = 48 m/s ≈ 50 m/s
- Time taken = 0.25 seconds

- $a = v / t = (50 - 0) / 0.25 = 200\ m/s^2$

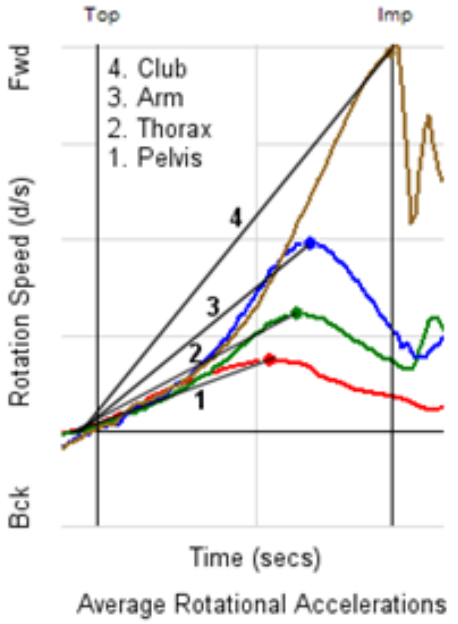
- Gravity = $9.81\ m/s^2 \approx 10\ m/s^2$
- 200 / 10 = 20 g's

- Incredible Athlete!



Angular Acceleration

- Acceleration in a circle around an axis
- Rate of change of angular velocity
- $\alpha = \omega / t$ (degrees/second^2)
- Angular acceleration produces an increase in your rotational speed
- It is also the slope of the angular velocity curve
- So from Kinematic Sequence we can get an idea of the accelerations
- Accel and Decel both occur in the Downswing



Angular ≈ Rotational ≈ Turning ≈ Circular

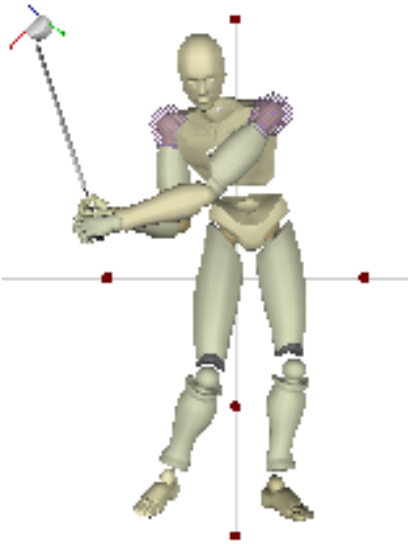
The Kinematic Sequence

A practical example of angular velocity and acceleration in action

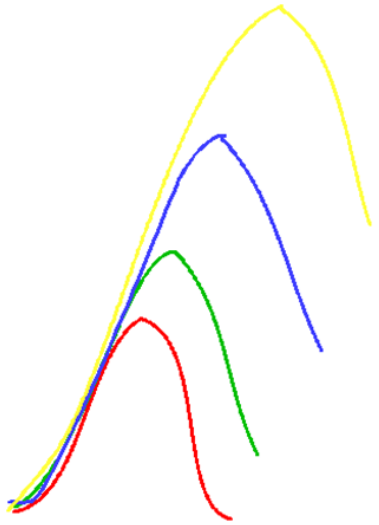
The signature of an efficient swing

Kinematic Sequence

- Also Known As
  - Summation of Speed Principle
  - Proximal-to-Distal Sequencing
  - Kinetic Link



- Sequential accelerations and decelerations
  - Larger, stronger, slower, proximal segments move first
  - Followed by the smaller, faster, distal segments

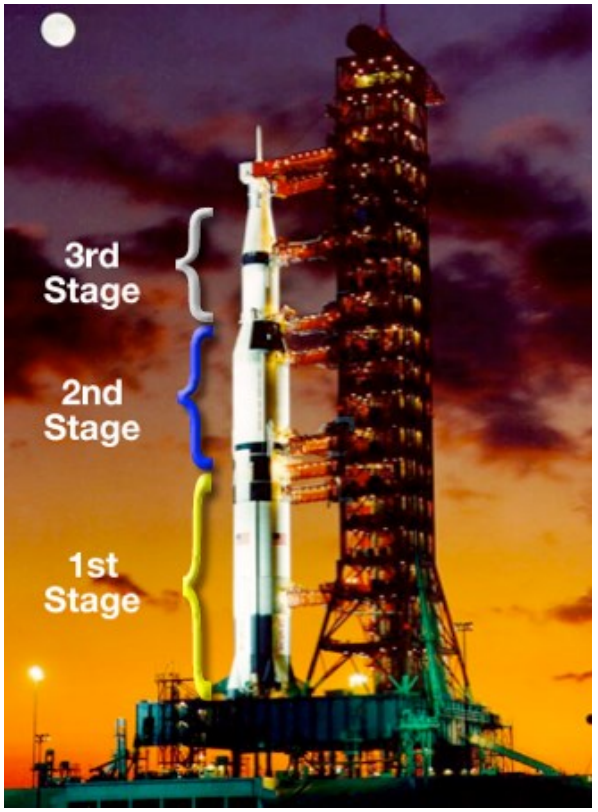


Kinematic Sequence

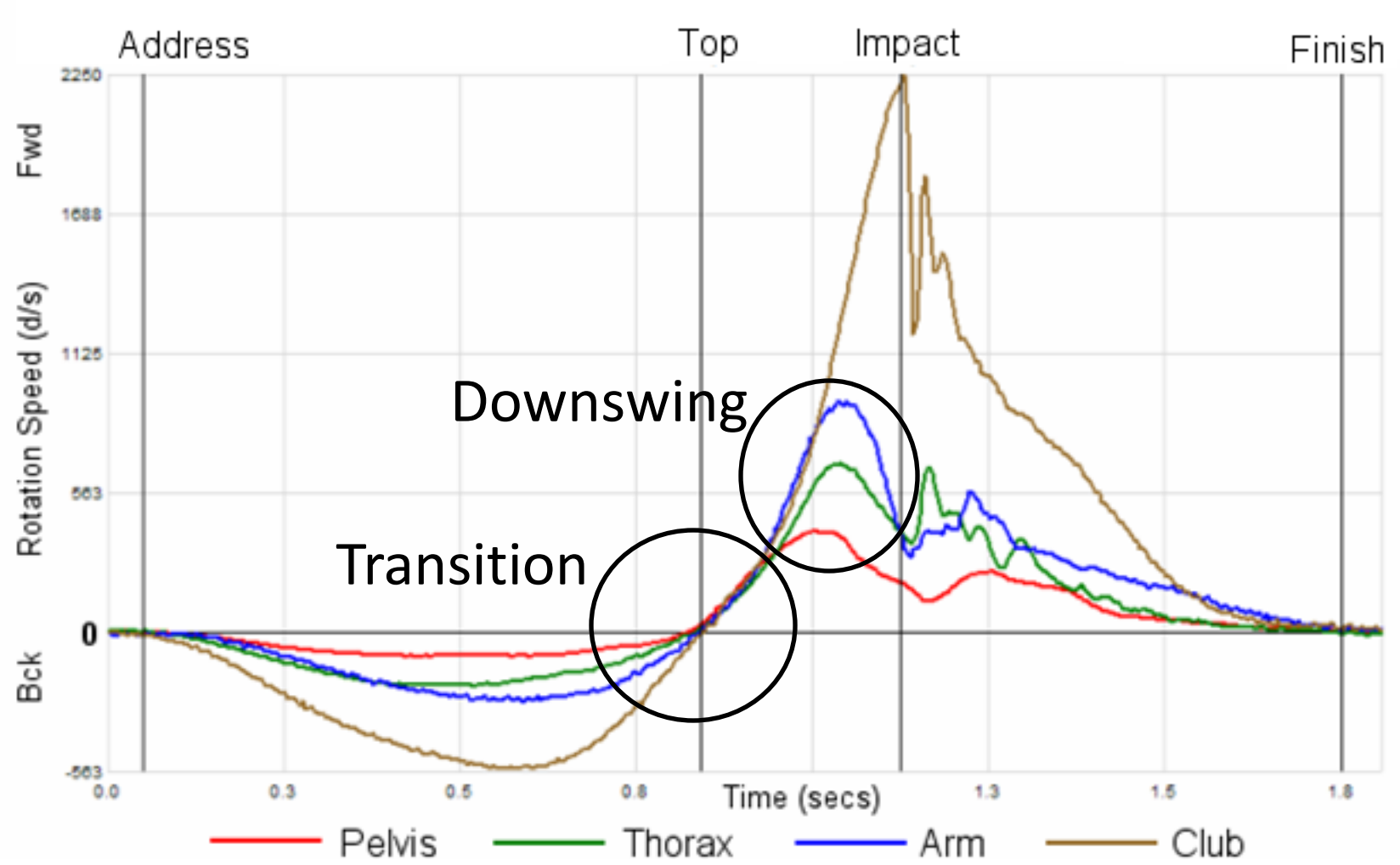
- Present in Many Sports
  - Swinging, Hitting, Throwing, Kicking, Punching
- Goals
  - Maximize Velocity of an Object
    - Club, Bat, Ball, Racket, Fist
  - Achieve High Velocity and Accuracy with Reduced Effort

Analogies

- Rocket Ship
  - Stages 1, 2, 3
- Car with Manual Shift
  - Gears 1st, 2nd, 3rd, 4th



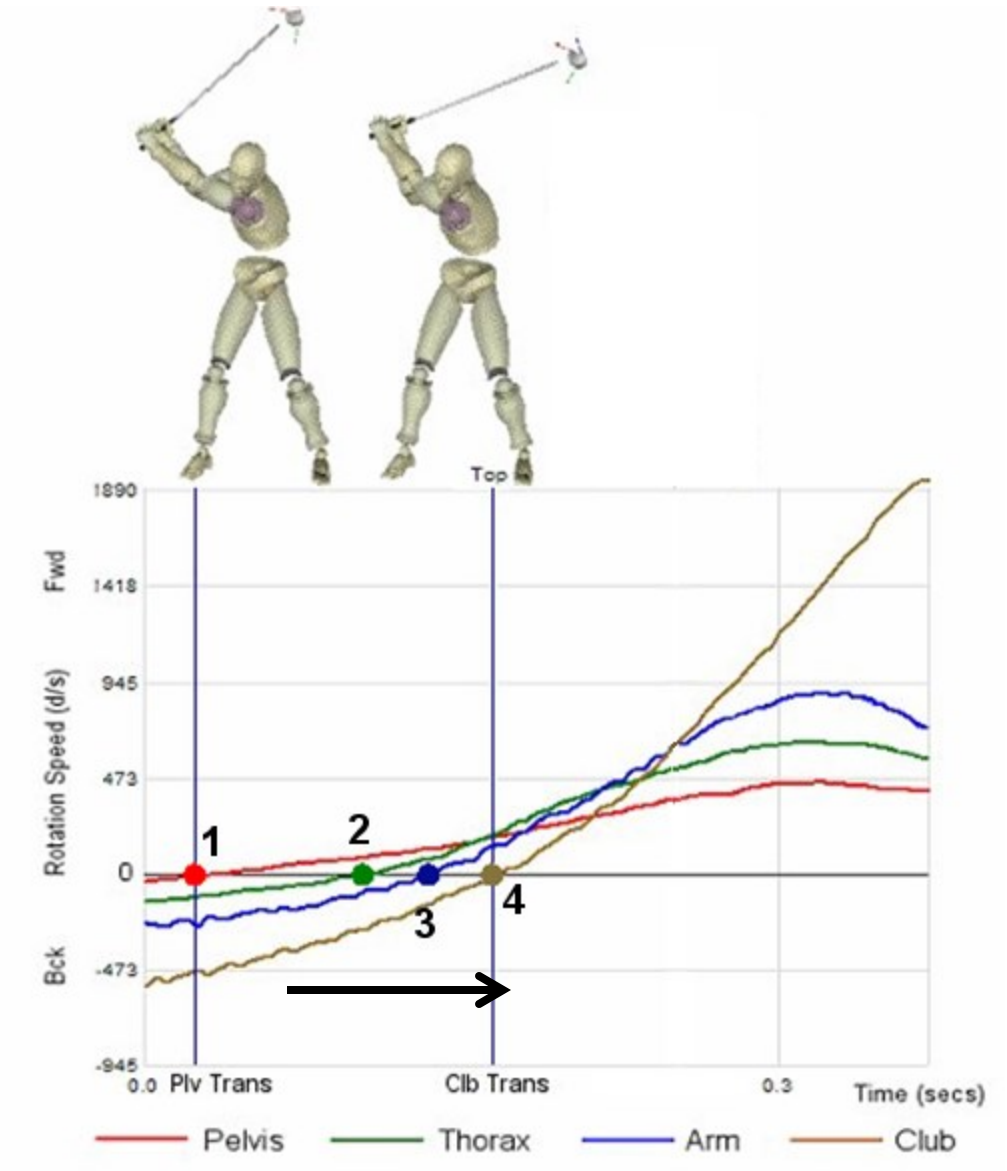
The Kinematic Sequence Graph



Transition Sequence

Setting Up the Downswing with Power and Direction

The Transition Sequence

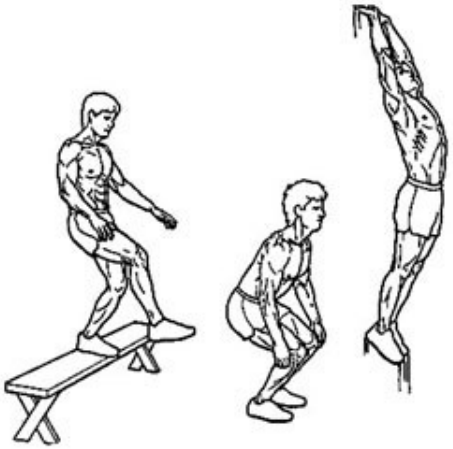


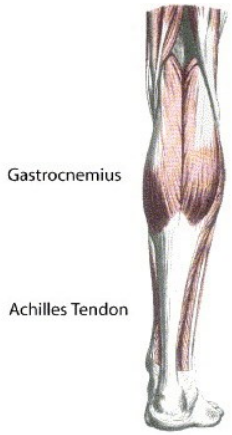
- Transition Phase
- Transition from Backswing to Downswing
- From First Segment Turn Around to Last
- Sequential Order, Large to Small segments
- Pelvis, Thorax, Arm, Club
- Advantage from Stretch-Shorten Cycle of Muscle

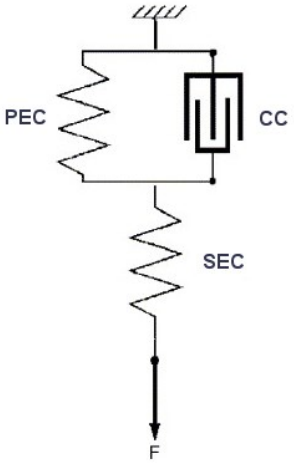
The Stretch Shorten Cycle of Muscle

Eccentric muscle contraction (***Stretch***)
Quickly followed by
Concentric muscle contraction (***Shorten***)

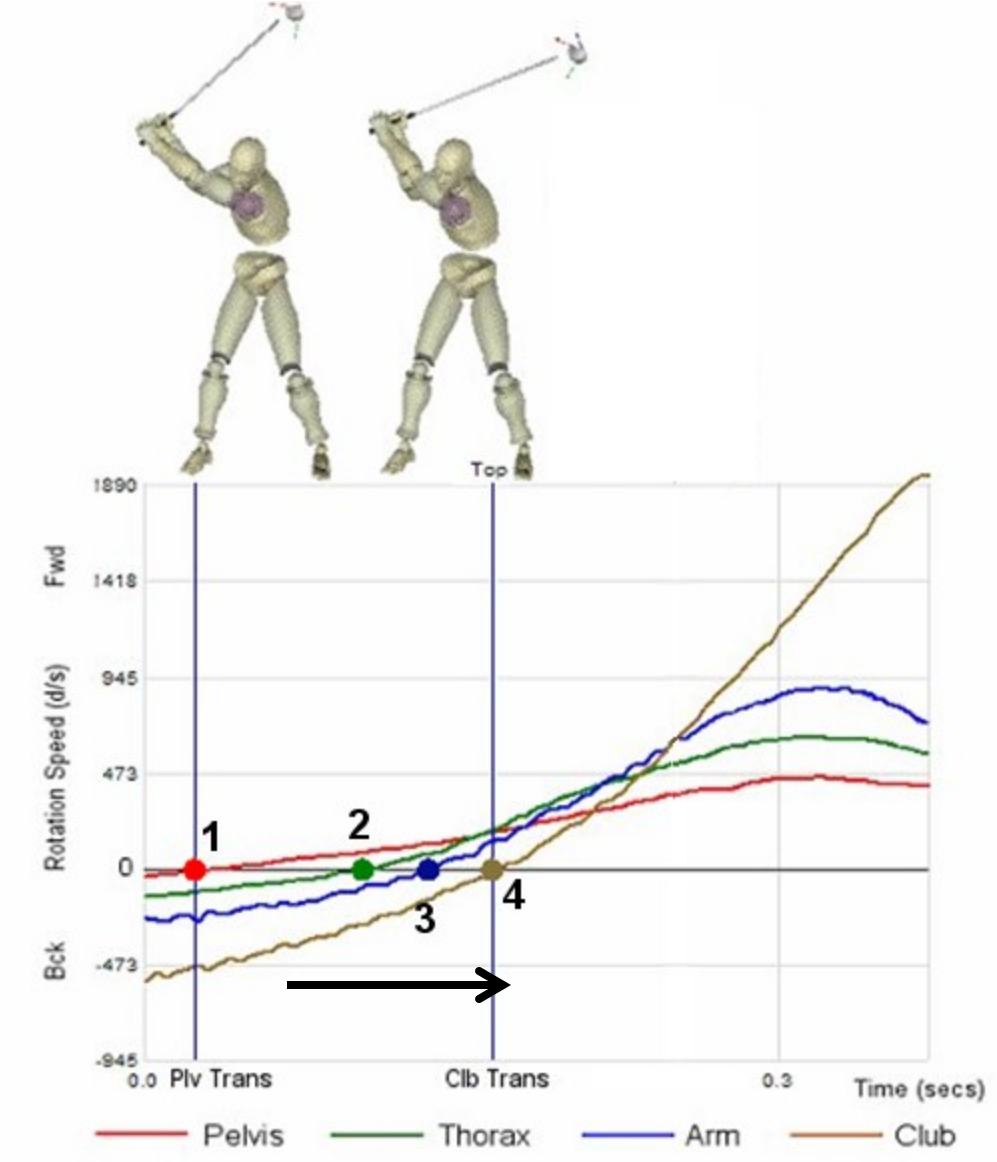
- Increases Force of Muscle Contraction
  - Pre-Stretch – raises initial muscle tension level
  - Stored Elastic Energy – returned during concentric contraction
  - Stimulates Stretch Reflex







Stretch-Shorten Cycle Benefit at Each Joint



Extra Stretch at Each Joint During the Downswing

- 1 –> 2 (Core)
  - X-Factor Stretch
- 2 –> 3 (Shoulder)
  - Shoulder Adduction Stretch
- 3 –> 4 (Wrist)
  - Wrist Lag Stretch
  - Transition or Pre-Release

Transition Phase of Pros

- Sequential Order of Transition
  - Pelvis, Thorax, Arm, Club
  - Lateral Pelvis Motion before Rotational
- Downswing Joint Stretch
- Timing of Transition
  - Not too long and not too short
  - Dependent on golfer
  - Slow v Fast Twitch
  - Flexible v Tight

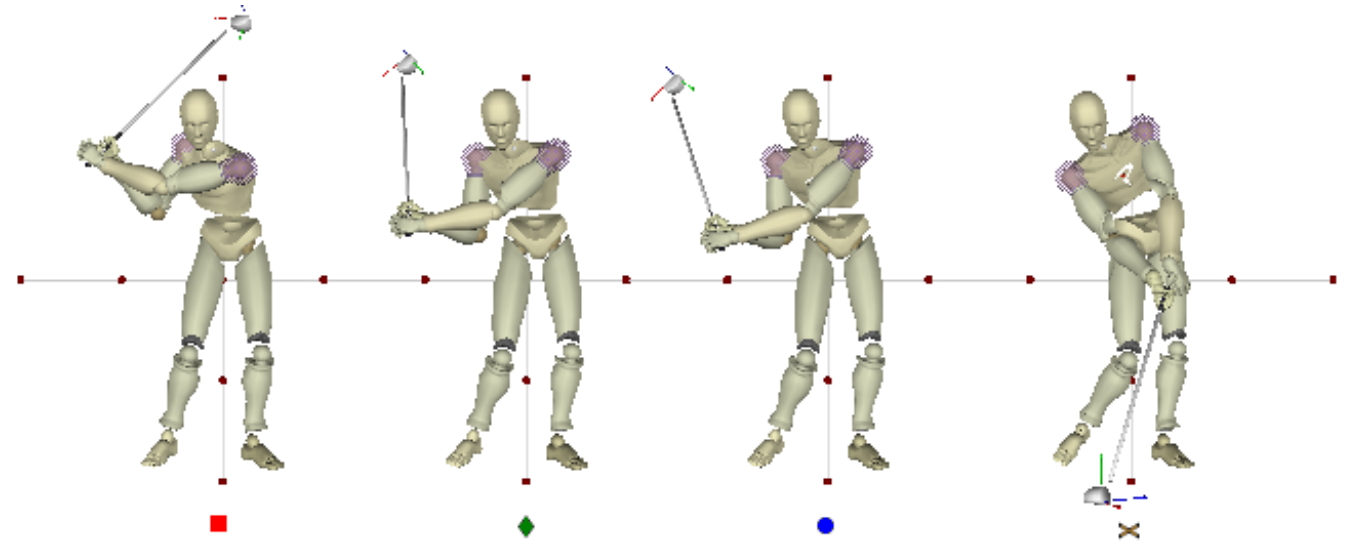
Degrees	Core	Shoulder	Wrist
Men	5	2	6
Women	6	2	2

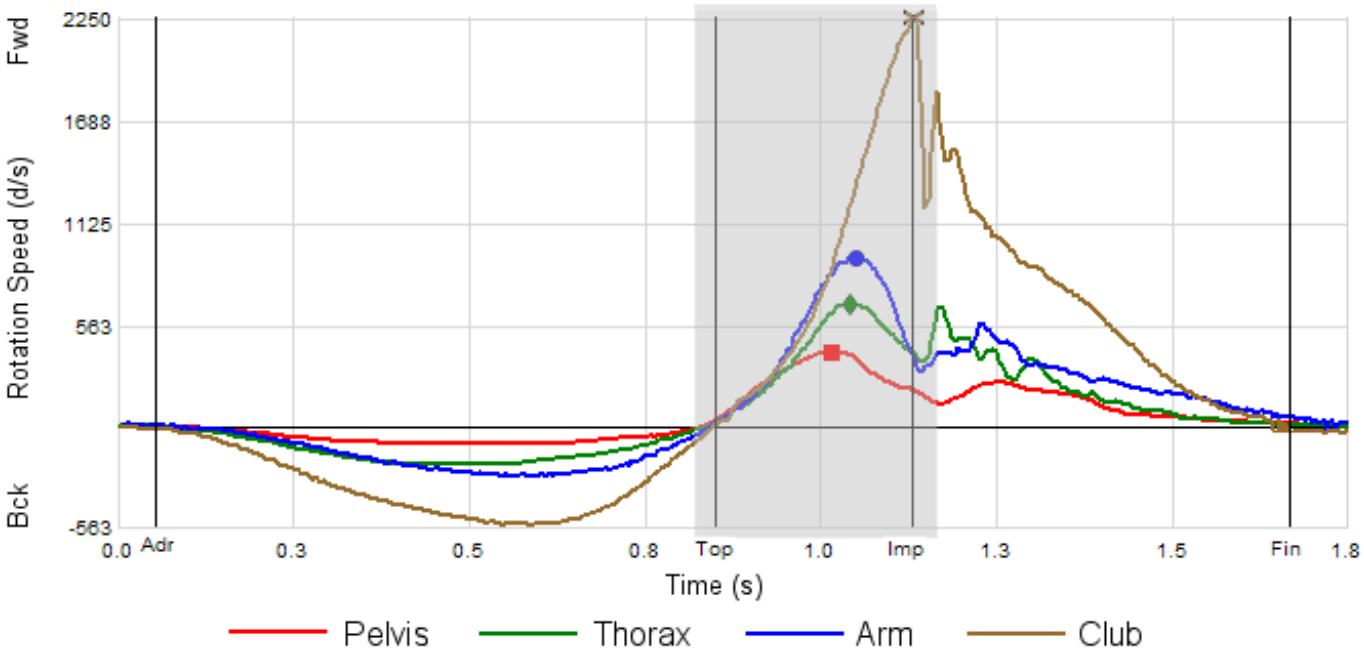
Millisec.	Total	Core	Shoulder	Wrist
Men	56	28	18	10
Women	56	37	16	3

Downswing Sequence

Creating Clubhead Speed

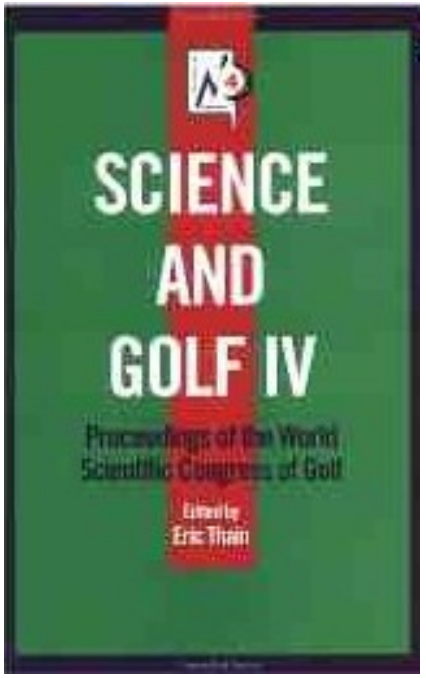
Downswing Sequence



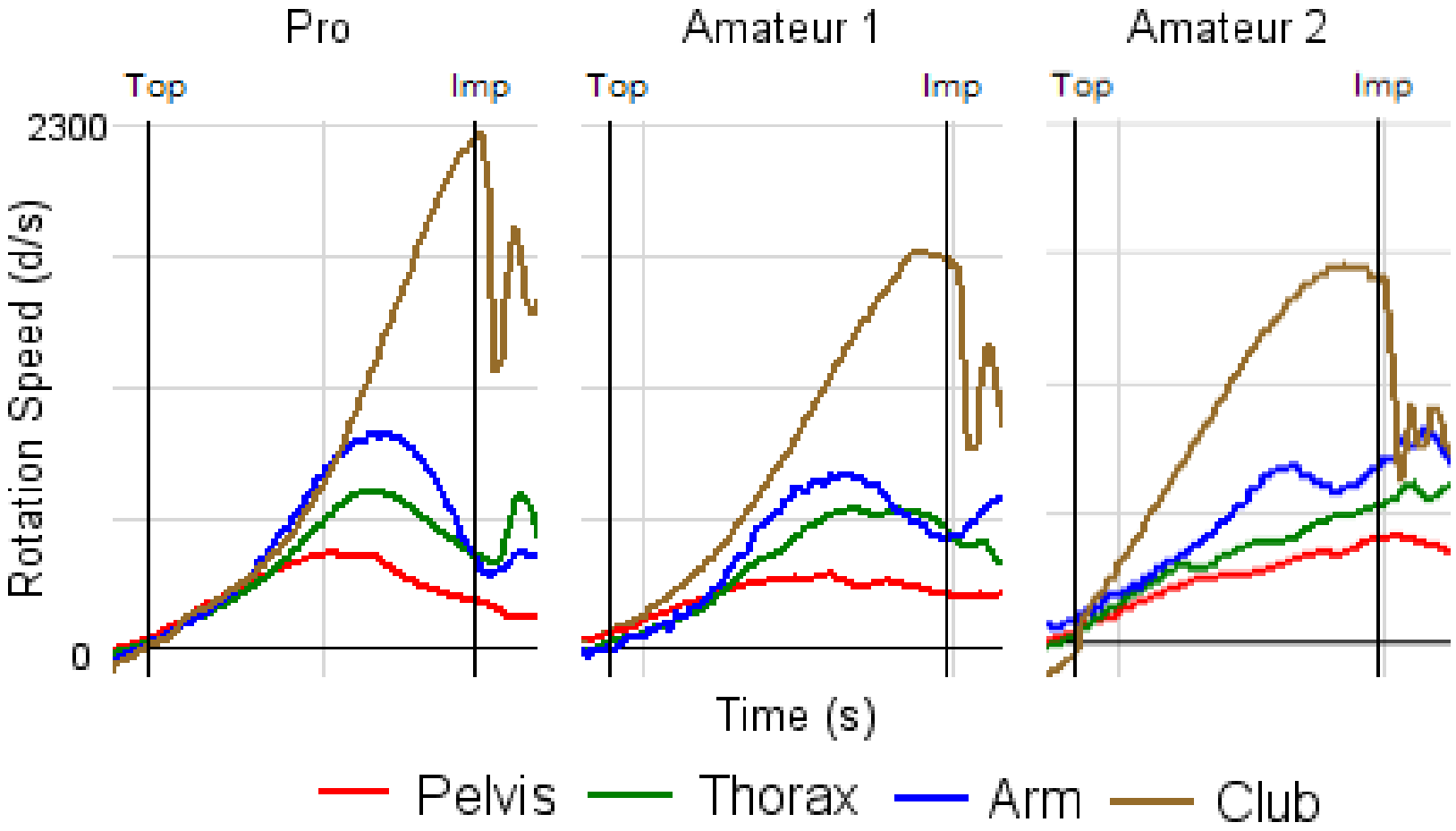


Cheetham and TPI Biomech Advisory Board (2008)

- Comparison of Kinematic Sequence Parameters between Amateur and Professional Golfer
  - World Scientific Congress of Golf
  - Science and Golf V
  - Validated differences between Amateurs and Pros
  - The Kinematic Sequence gives us measurements that define high performance



Three Examples



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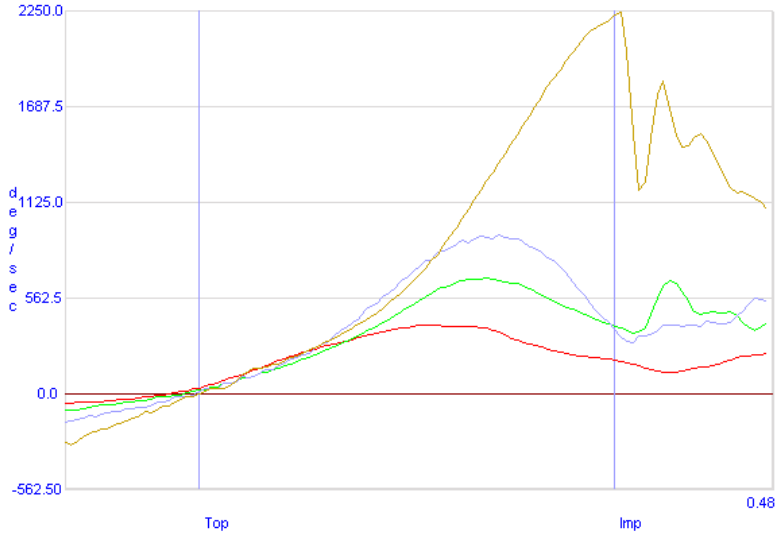
Downswing Sequence

Angular Velocity: Pelvis Thorax Arm Club



Sequence Parameters

		Pelvis		Thorax		Arm		Club	
Peak Order	order	1		2		3		4	
Peak Timing Pre-Impact	ms	129	77 to 113	88	54 to 89	79	62 to 81	0	-1 to 5
Peak Speed	d/s	402	415 to 522	678	629 to 764	934	888 to 1038	2230	2108 to 2306
% of Max	%	18	18 to 23	30	28 to 34	42	40 to 46	100	100 to 100
Acceleration	d/s/s	2305	1717 to 2595	3291	2579 to 3856	4601	4190 to 5942	7879	7474 to 9734
Deceleration	d/s/s	1590	1223 to 2734	3206	1508 to 3889	7023	5764 to 8356	8838	7821 to 9375

Segmental Interactions

		Pelvis-Thorax		Thorax-Arm		Arm-Club	
Time Between Peaks	ms	42	5 to 43	8	-18 to 17	79	61 to 79
Angular Speed Gain	d/s	276	184 to 272	255	211 to 321	1297	1160 to 1327
Gain Factor	ratio	1.7	1.4 to 1.6	1.4	1.3 to 1.5	2.4	2.2 to 2.4

Contribution by Joint

		Legs		Core		Shoulder		Wrist	
% Contribution	%	18	18 to 23	12	8 to 12	11	9 to 14	58	53 to 59

Men and Women Tour Players - Driver

d/s	Men	Women
Pelvis	479	500
Thorax	705	710
Arm	975	940
Club	2244	1898

Maximum Rotation Velocity

d/s	Men	Women
Legs	479	500
Core	227	210
Shoulder	269	229
Wrist	1269	958

Velocity Gain across Joint

%	Men	Women
Legs	21	26
Core	10	10
Shoulder	12	12
Wrist	56	50

% Contribution by Joint

Forces and Motion Workshop

- Motion -> Kinematics
  - Dr. Phil Cheetham
- Forces -> Kinetics
  - Dr. Sasho MacKenzie
- Keynote Speaker
  - Chris Como
- Legacy Resort, Phoenix AZ
- November 13, 14 - 2015

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END