# Relationship of Club Handle Twist Velocity to selected Biomechanical Characteristics of the Golf Drive

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# Interesting to See What World Class Golfers Do During the Downswing

- They:
  - Maintain a Fixed Wrist Angle and,
  - Release the Wrist Angle Late,
  - Then Roll Arms and Twist Club Handle, to
  - Square the Club Face into Impact

- Some Twist the Handle Slowly
  - Low Handle Twist Velocity
  - As Low as ~600 °/s

- Some Twist the Handle Fast
  - High Handle Twist Velocity
  - As High as ~2400 °/s

- Which is Better?
- What are the Biomechanical Characteristics?

# Define Mechanical Factors using a Deterministic Model

Dr. James Hay

Hay and Reid (1988)

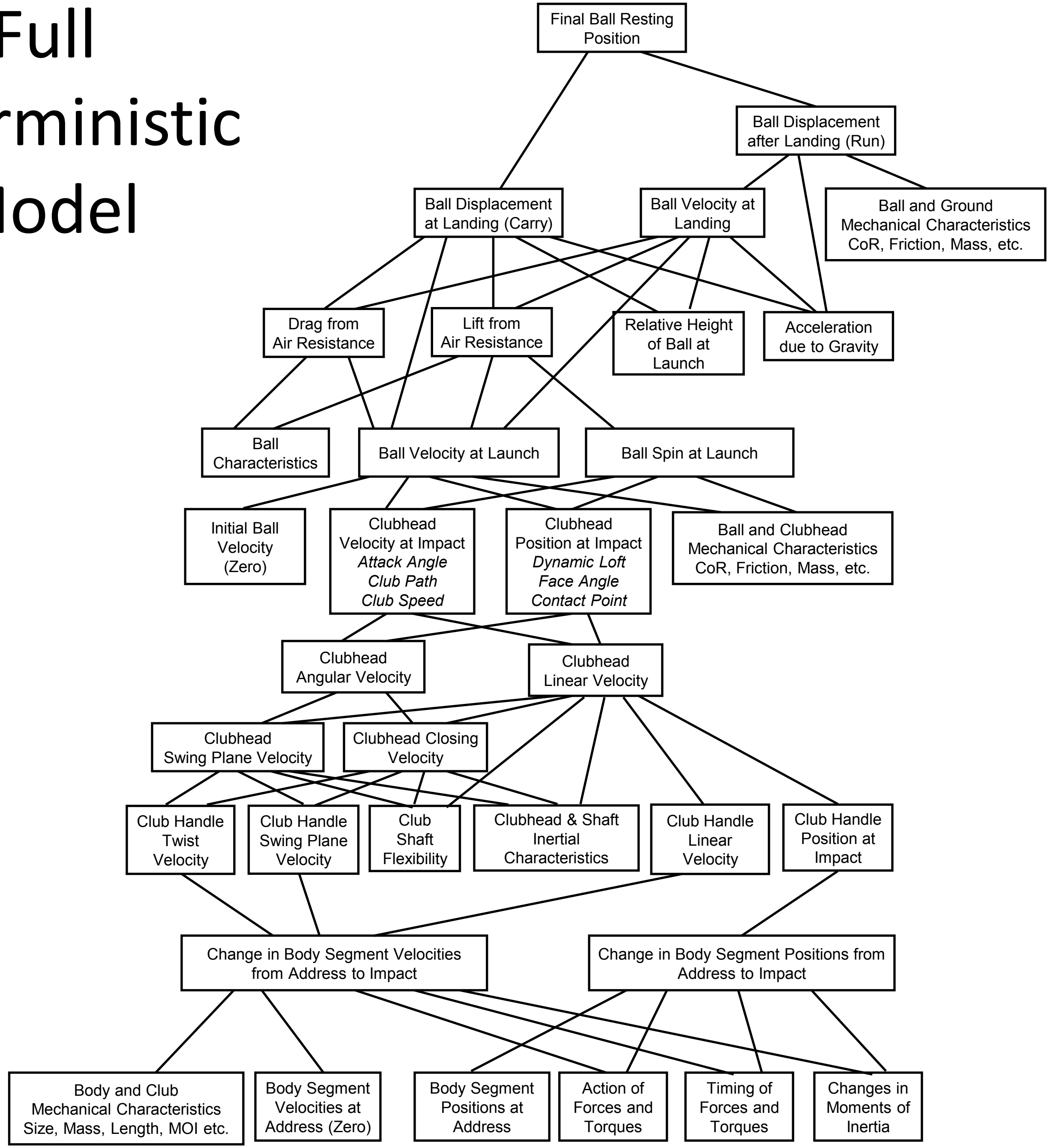
How Does

Handle Twist Velocity

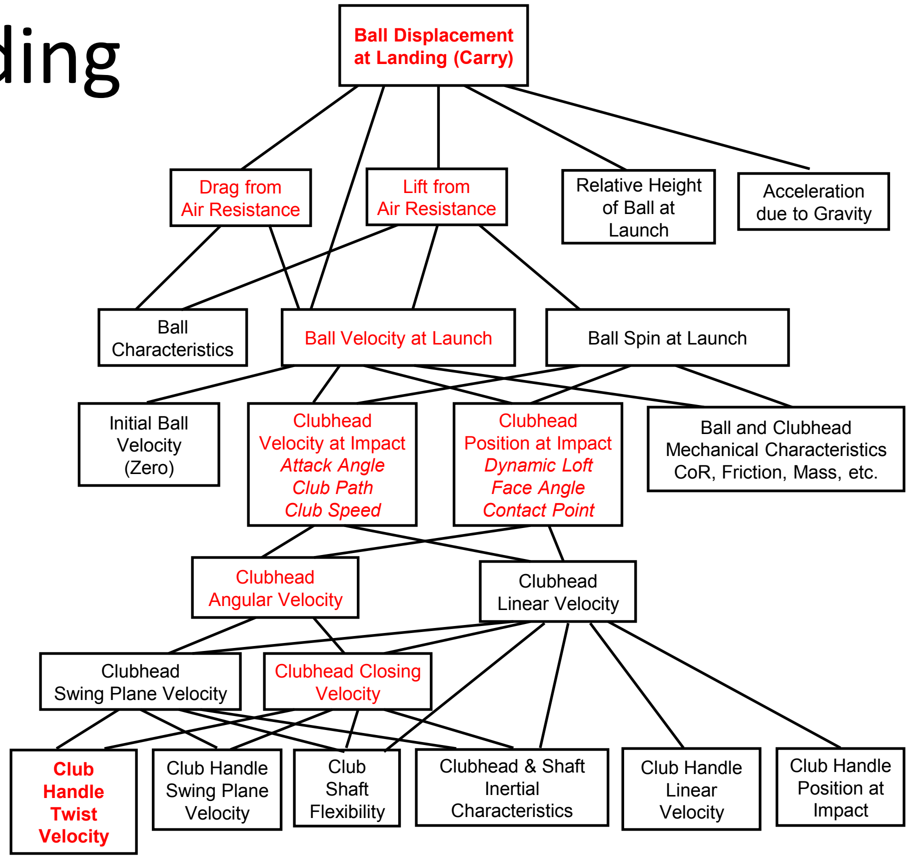
Affect the Outcome?

Final Ball Resting Position

# Full Deterministic Model



# Model from Club Handle to Ball Landing

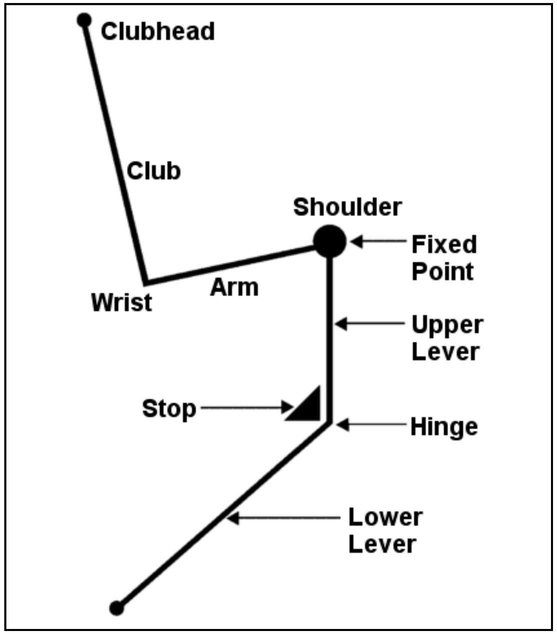



Club Handle Twist Velocity

- Angular velocity about the long axis of the handle

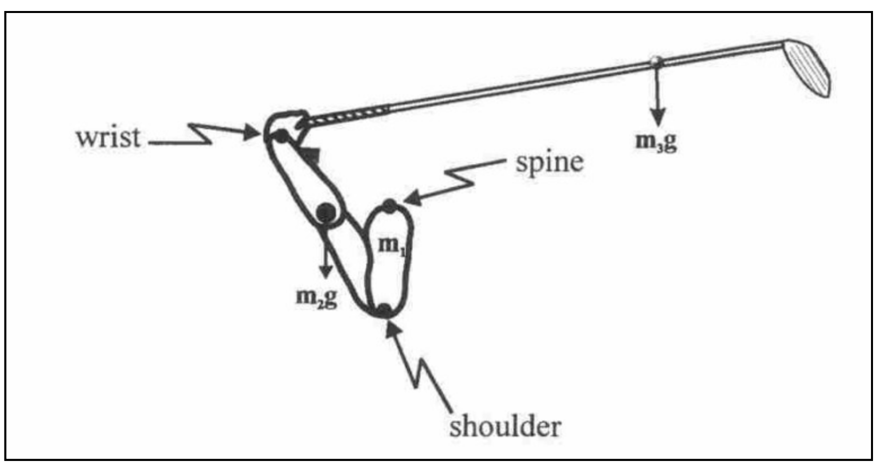
# Literature Review

# 2D Pendulum Models




## Double Pendulum

- Williams (1967)
- Cochran and Stobbs (1968)
  - Search for the Perfect Swing
- Lampsa (1975)
- Budney and Bellow (1979)
- Campbell and Reid (1985)
- Milne and Davis (1992)
- Jorgensen (1999)
  - The Physics of Golf
- Pickering and Vickers (1999)




Club would hit ball with heal?

## Triple Pendulum

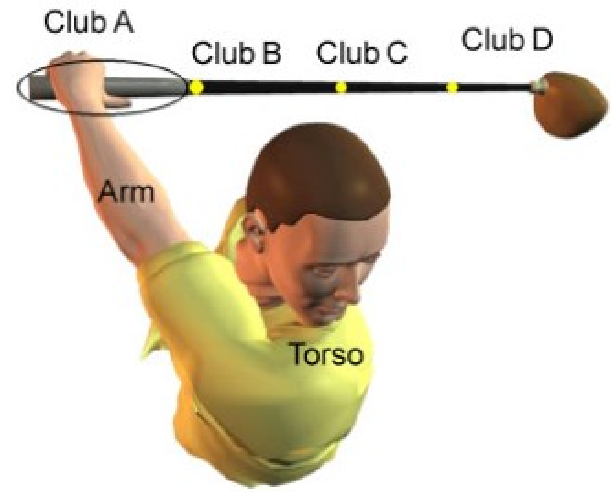
- Sprigings and Neal (2000)
- Sprigings and Mackenzie (2002)

# 3D Models

## Nesbit (2007)

- Commissioned by the USGA
- Full-Body 15 Segment Model
- Club Shaft can rotate in all 3-axes
- Alpha, Beta, Gamma
- Gamma is Handle Twist
- Can add 1.5m/s to Swing Speed

Image from:
Nesbit, S. M. (2007). Development of a full-body biomechanical model of the golf swing. *International Journal of Modelling and Simulation*. 27(4), 392-404

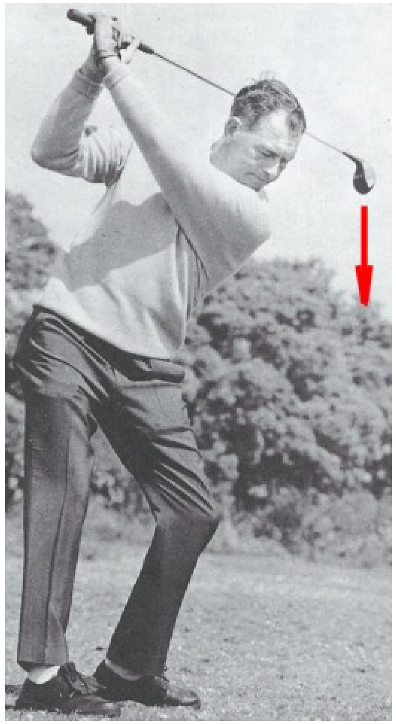


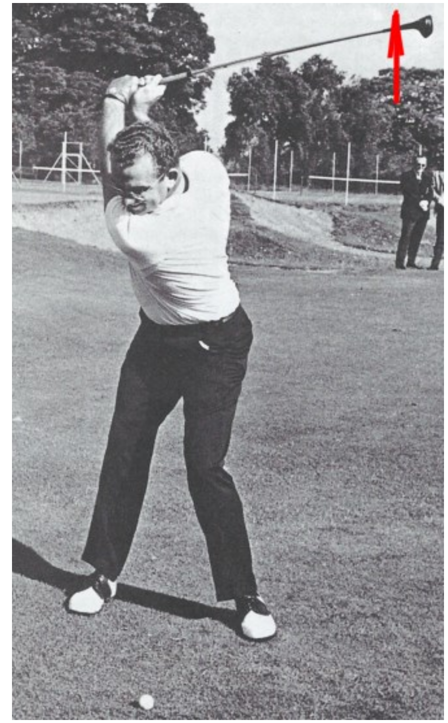

## MacKenzie and Sprigings (2009)

- Six Segment Model
- Arm can Rotate around Long Axis
- Allows the face to square up at impact

Image from:
MacKenzie, S. J., & Sprigings, E. J. (2009b). Understanding the role of shaft stiffness in the golf swing. *Sports Engineering*, *12*(1), 13-19.

# Cochran and Stobbs (1968), Search for the Perfect Swing
## Rollers, Squares and Pushers





Roller Method
- High HTV
- Open Faced

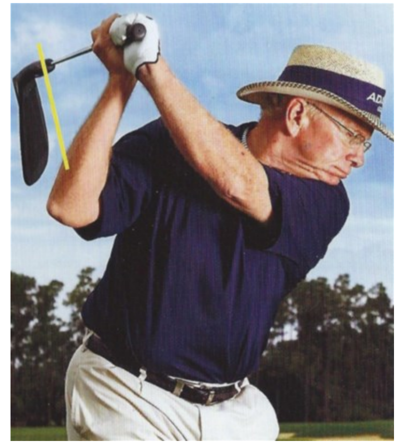
Pusher Method
- Low HTV
- Closed Faced

Images from: Cochran, A., & Stobbs, J. (1968). *Search for the perfect swing* (5th ed.). Chicago: Triumph Books

# Suttie (2011)

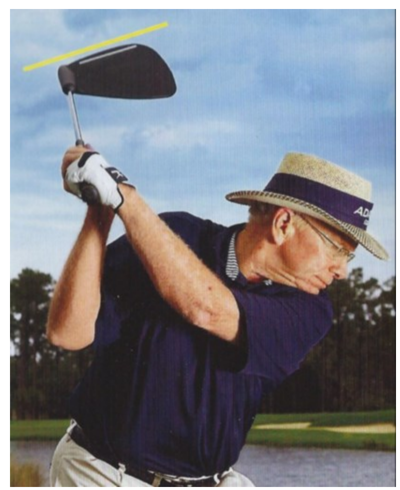
## Open Face Method

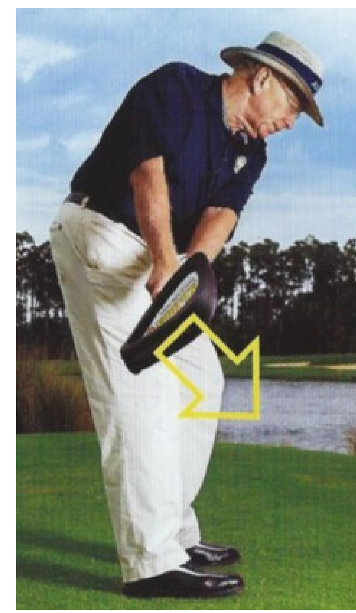
- High HTV
- Rollers



## Closed Face Method

- Low HTV
- Pushers





Images from: Suttie, J. (2011). The fine art of club control. In D. DeNunzio (Ed.), *The Best Driving Instruction Book Ever!* (pp. 90-101). New York: Time Home Entertainment Inc.

# Methods

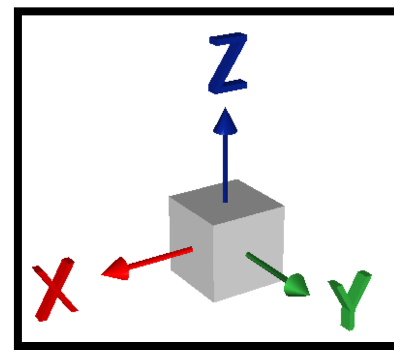
# System and Software

Capture, Calculations and Display

Protocol, Database and Reports

# AMM3D Electromagnetic

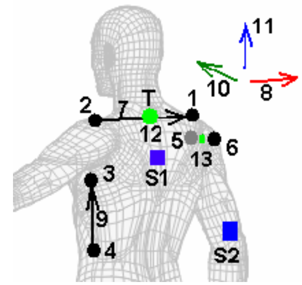
- Polhemus, Inc.
  - Liberty Hardware
- Transmitter
  - Stationary 4” Cube
  - 3 Orthogonal Coils
  - Global Coordinate System
- Sensors
  - On Body and Club
  - Wired Moving ½” Cubes
  - 3 Orthogonal Coils
  - Local Coordinate Systems

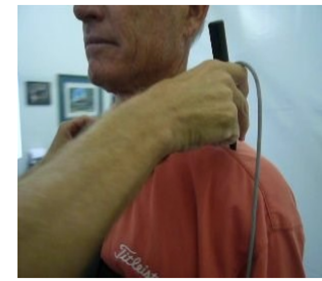


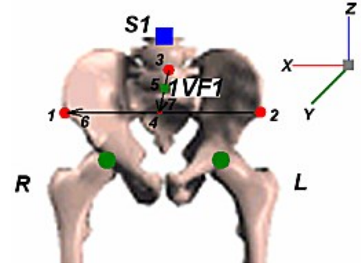

- Advantages
  - 12 Sensor Full-Body Model
  - Fast 240 Hz
  - Real-Time
  - 6 DOF (x, y, z, pitch, yaw, roll)
  - Accurate Anatomical Alignment
- Disadvantages
  - Don’t have clubhead directly
  - Compute it from rigid shaft model

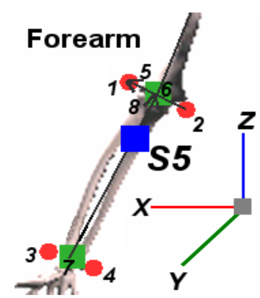
# Anatomical Alignment

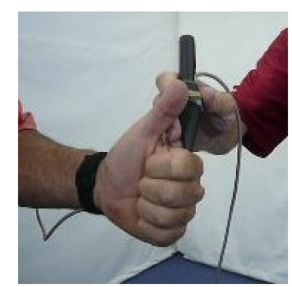
- Local coordinate systems created in every body segment and club
  - Digitizing at least 3 bony landmarks on each segment and the club.
  - Medial/Lateral, Anterior/Posterior and Superior/Inferior axes in each segment
  - Using the Cross Product Method
- Shin is an easy example

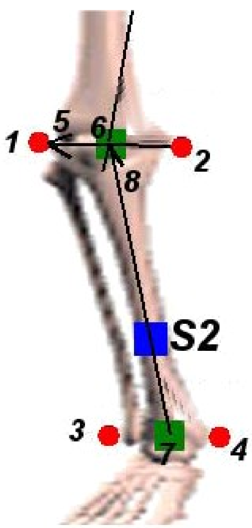


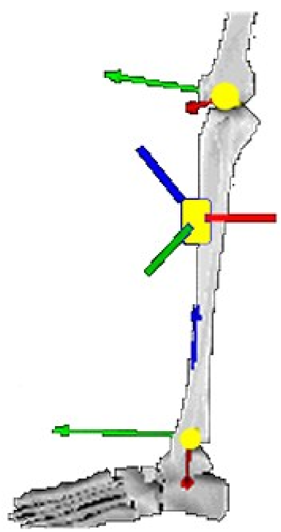





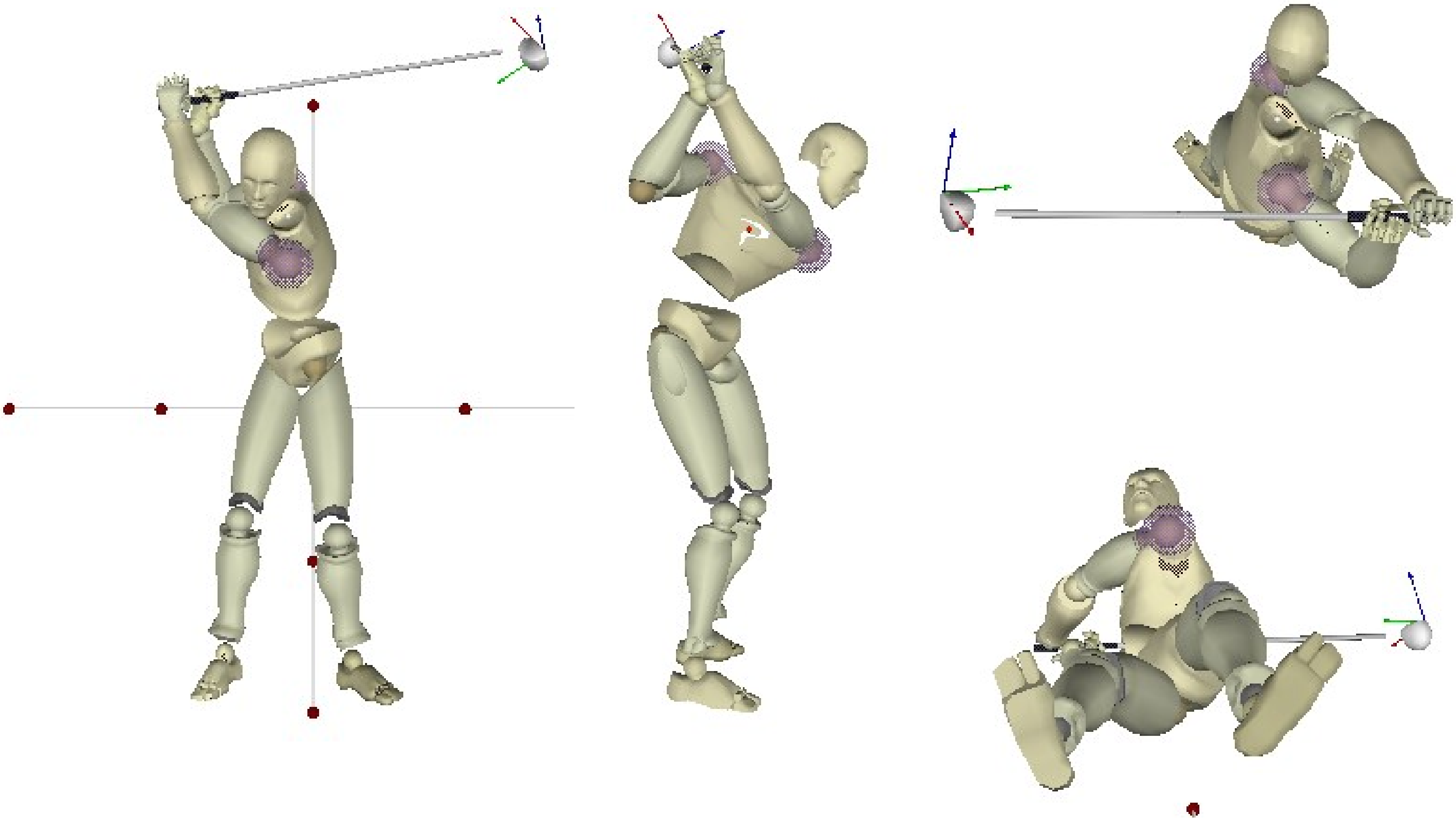



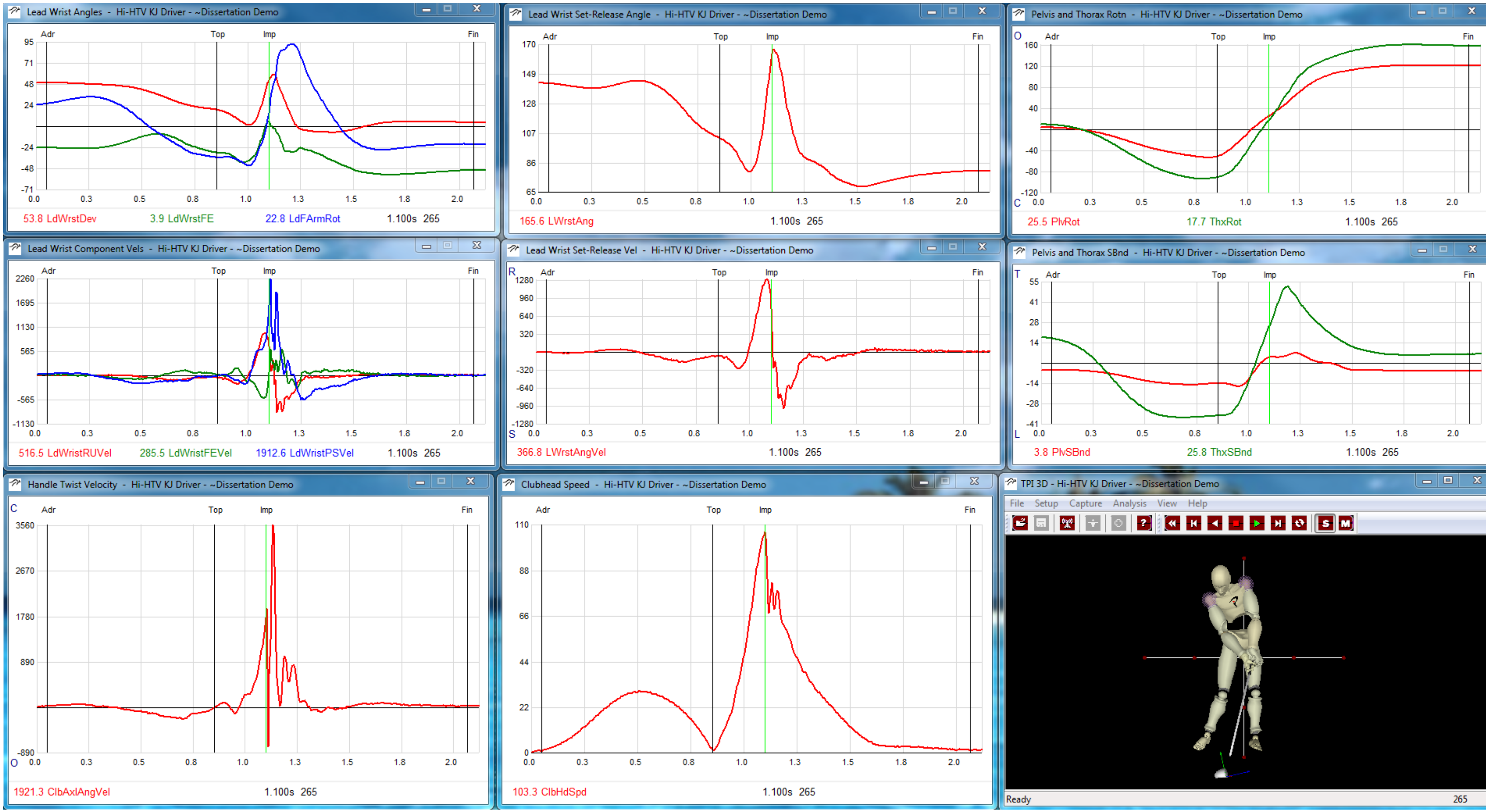


# Full Body 3D Avatar



# Analysis Layout for Our Study



# Comparison Table and Database

Data Demo | Pro2 | Positions | 97.8 C to 83.4 C

| Parameter | Units | Adr | HB | Top | HD | Imp | HF | Fin |
|---|---|---|---|---|---|---|---|---|
| Pelvis Rotation (Open-Closed) | deg | 2.5 O | 17.5 C | 55.8 C | 30.4 O | 41.4 O | 50.6 O | 113.2 O |
| Pelvis Bend (Fwd-Back) | deg | 23.8 F | 21.4 F | 17.2 F | 14.3 F | 10.0 F | 10.4 F | 14.5 F |
| Pelvis Side Bend (Trail-Lead) | deg | 0.3 L | 3.7 L | 8.5 L | 11.7 T | 12.0 T | 10.4 T | 7.7 T |
| Thorax Rotation (Open-Closed) | deg | 13.3 O | 29.8 C | 100.0 C | 3.5 O | 23.5 O | 55.6 O | 150.6 O |
| Thorax Bend (Fwd-Back) | deg | 36.3 F | 35.7 F | 6.6 B | 34.3 F | 24.1 F | 2.5 F | 36.5 B |
| Thorax Side Bend (Trail-Lead) | deg | 16.0 T | 13.5 L | 40.8 L | 12.6 T | 27.0 T | 48.2 T | 9.7 T |
| Pelvis Sway (To-Away) | in | 0.0 | 1.6 A | 0.8 A | 2.4 T | 2.5 T | 3.4 T | 8.4 T |
| Pelvis Thrust (Fwd-Back) | in | 0.0 | 0.5 B | 1.8 F | 2.1 F | 2.8 F | 3.3 F | 2.9 F |
| Pelvis Lift (Up-Down) | in | 0.0 | 0.0 | 1.8 D | 1.1 U | 1.5 U | 1.3 U | 0.2 U |
| Thorax Sway (To-Away) | in | 0.0 | 1.4 A | 1.2 A | 0.0 | 2.0 A | 4.5 A | 5.8 T |
| Thorax Thrust (Fwd-Back) | in | 0.0 | 0.1 F | 2.4 F | 0.5 B | 0.9 B | 0.6 B | 2.5 F |
| Thorax Lift (Up-Down) | in | 0.0 | 0.8 D | 2.3 D | 1.7 U | 2.2 U | 0.9 U | 1.3 U |
| Spine Rotation (Open-Closed) | deg | 11.2 O | 13.9 C | 47.9 C | 27.9 C | 20.5 C | 5.8 C | 31.5 O |
| Spine (Flex-Ext) | deg | 12.5 F | 14.3 F | 23.8 E | 20.0 F | 14.1 F | 7.9 E | 51.0 E |
| Spine Side Bend (Trail-Lead) | deg | 16.3 T | 9.8 L | 32.3 L | 1.0 T | 15.0 T | 37.8 T | 2.0 T |
| Head Rotation (Open-Closed) | deg | 3.7 C | 13.7 C | 19.5 C | 4.5 C | 0.6 C | 3.8 O | 77.4 O |
| Head Bend (Fwd-Back) | deg | 46.3 F | 42.3 F | 33.2 F | 49.1 F | 52.0 F | 49.8 F | 8.8 B |
| Head Side Bend (Trail-Lead) | deg | 1.0 L | 9.7 L | 10.0 L | 6.9 T | 8.6 T | 11.0 T | 29.7 T |
| Head Sway (To-Away) | in | 0.1 T | 2.8 A | 3.7 A | 2.1 A | 3.1 A | 4.6 A | 12.3 T |
| Head Thrust (Fwd-Back) | in | 0.0 | 0.2 B | 0.8 F | 0.2 B | 0.7 B | 0.7 B | 2.6 B |
| Head Lift (Up-Down) | in | 0.0 | 0.5 D | 0.2 D | 0.5 D | 0.3 D | 0.7 D | 8.2 U |
| Neck Rotation (Open-Closed) | deg | 18.1 C | 15.7 O | 80.7 O | 10.8 C | 28.5 C | 56.0 C | 71.3 C |
| Neck (Flex-Ext) | deg | 10.0 E | 6.7 E | 39.8 E | 14.7 E | 27.8 E | 47.3 E | 27.8 E |
| Neck Side Bend (Trail-Lead) | deg | 17.1 T | 3.8 L | 30.8 L | 5.7 T | 18.5 T | 37.2 T | 20.0 L |

Rng: PGA-Driver Prj: Full Body 12R TPI 7-14-04

# Databases of Swings

- Swings Captured at TPI in Oceanside, CA
  - 94 Male Professional Golfers from European and PGA Tour
  - 70 PGA Tour Professionals with Driving Statistics from www.pgatour.com
  - Two groups of 32, Lo-HTV and Hi-HTV
  - Also have 52 PGA Tour Winners

# Statistics

- Correlations
  - Pearson Product-Moment Correlations on full groups
  - 70 for Driving Accuracy Test
  - 94 for All other Selected Parameters
  - With Handle Twist Velocity

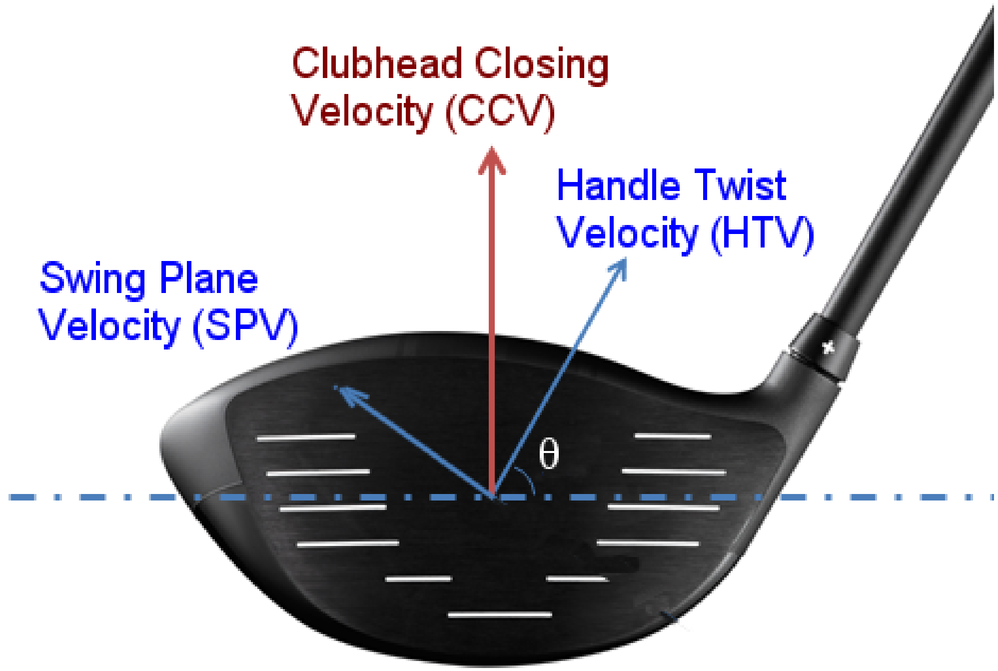
- Analysis of Variance
  - Two groups of 32 golfers from the 70 and 94 groups
  - Lo-HTV and Hi-HTV
  - Compare means of Hi-HTV and Lo-HTV groups for each parameter using single factor ANOVAs
  - Family-wise significance level of $p < .05$
  - Bonferroni corrected for the number of tests done in each study to avoid Type 1 Errors

# Limitations

- AMM3D measures club handle not clubhead
- Two Assumptions
  - Handle Twist Velocity is highly correlated with Clubhead Closing Speed
  - Rigid Clubhead Speed is highly correlated with Actual Clubhead Speed

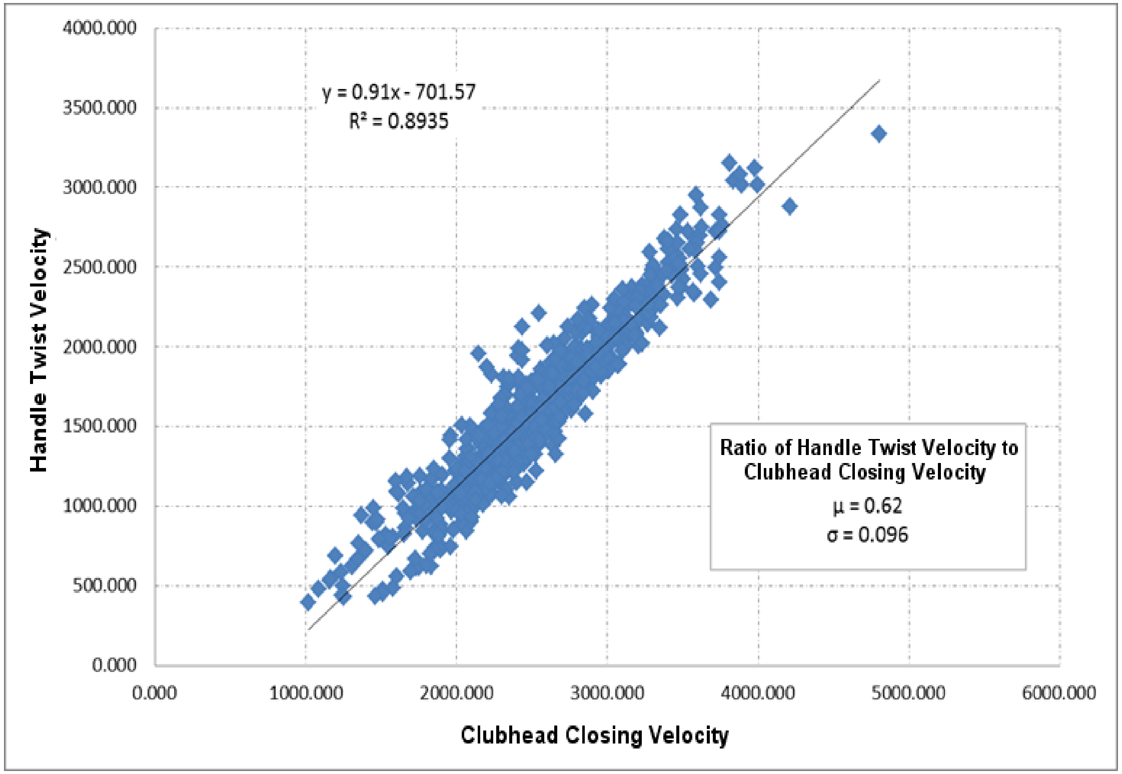
# Clubhead Closing Velocity

- CCV > HTV for Driver
  - Combination of both HTV and SPV
- Vertical Shaft
  - All HTV
  - Like Putting
- Horizontal Shaft
  - All SPV
  - Like Baseball




$CCV = HTV \sin(\theta) + SPV \cos(\theta)$
where $\theta$ is the Lie Angle
e.g. 58° for a driver

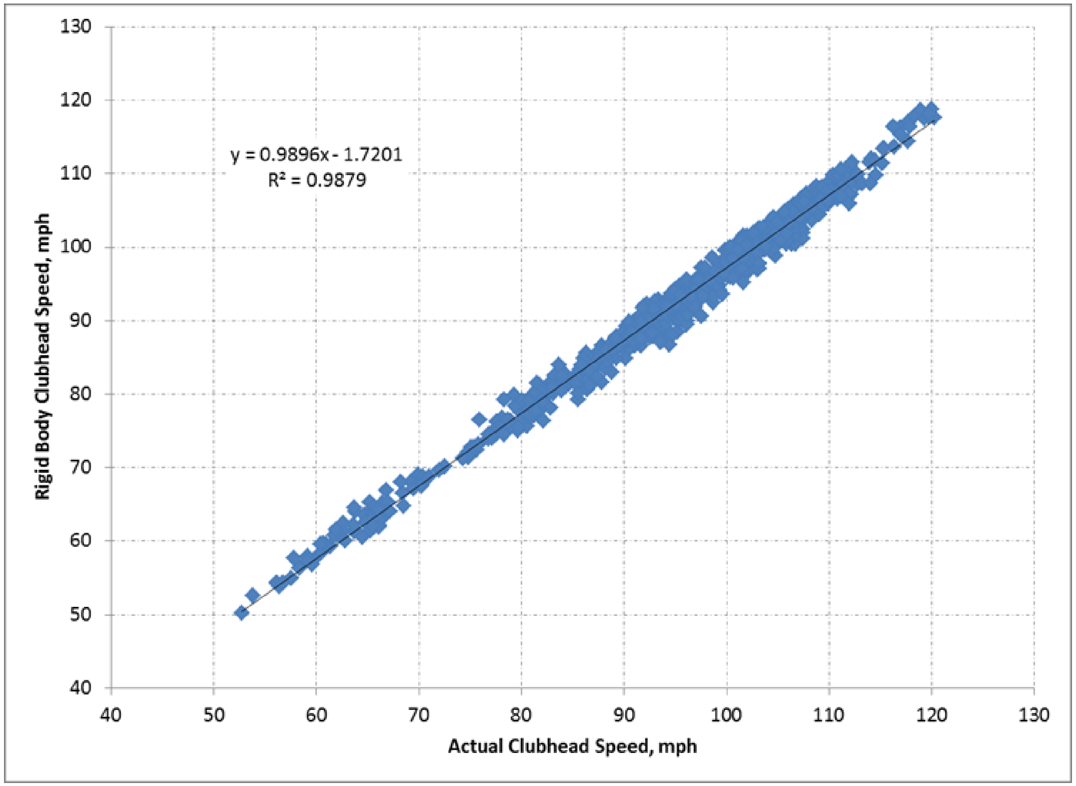
# Handle Twist Velocity and Clubhead Closing Velocity




- ENSO Motion Analysis System at Ping
- 150 players, 5 swings each
- CCV/HTV = 1.6
- CCV is faster than HTV
- Strongly Correlated
  - $r = 0.95$
  - $R^2 = 0.89$

P. Wood, personal communication, May 16, 2014

# Clubhead Speed - Rigid v Actual




P. Wood, personal communication, May 16, 2014

- ENSO Motion Analysis System at Ping
- 150 players, 5 swings each
- 52 mph to 120 mph

- Actual > Rigid
- 2.7 ± 1.43 mph

- Strongly Correlated
- $r = 0.99$
- $R^2 = 0.99$

# Data from Pre-Captured Swings at TPI

- Human Subjects Exemption
- By Independent Review Board at ASU
- Data Already in Existence
- No Subject Identification Divulged

# Study 1

-

# Handle Twist Velocity

Relationship to

# Clubhead Speed

and

# Driving Accuracy

# Definitions

**Clubhead Speed at Impact**

- Magnitude of the linear clubhead velocity
- How fast in m/s or mph of the clubhead is traveling

**Driving Accuracy**

- Percent of drives off the tee that come to rest in the fairway
- Found for each golfer on www.pgatour.com

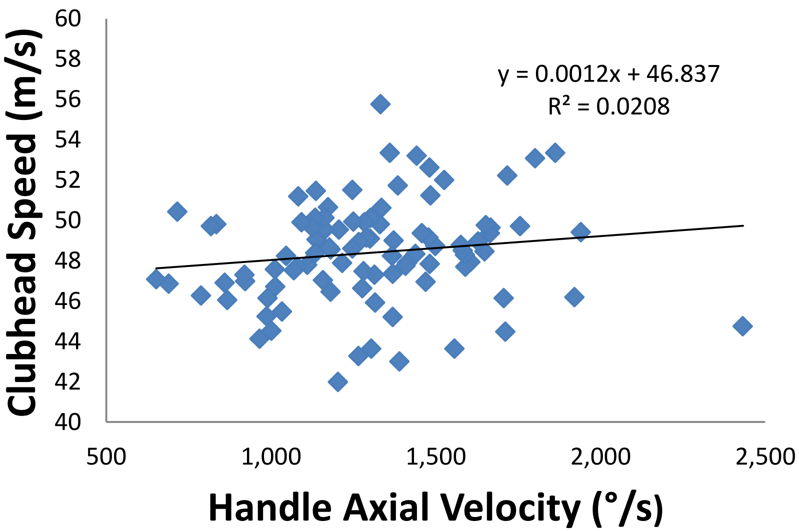
# Study1: HYPOTHESES

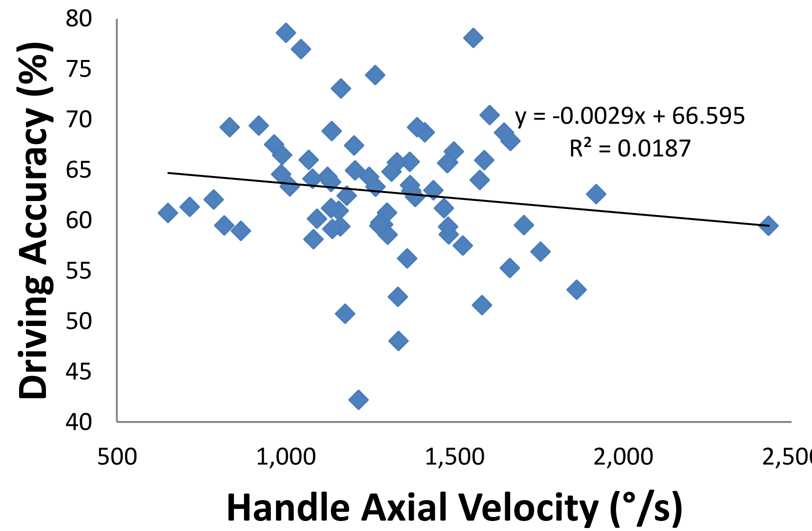
- **Clubhead Speed at Impact**
  Golfers with high HTV will have higher clubhead speed at impact

- **Driving Accuracy**
  Golfers with low HTV have better driving accuracy

# Descriptive Statistics and Correlations with HTV

| | n | Mean | SD | *r* | $R^2$ | Strength |
|---|---|---|---|---|---|---|
| Clubhead Speed (m/s) | 94 | 48.4 | 2.5 | 0.14 | 0.02 | Weak |
| Driving Accuracy (%) | 70 | 62.8 | 6.4 | -0.14 | 0.02 | Weak |



# ANOVAs with Hi-HTV v Lo-HTV

| | Hi-HTV | | Lo-HTV | | | | Sig at |
|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | F[1,62] | *p* | *p* < .025 |
| **Clubhead Speed (m/s)** | 48.9 | 2.5 | 48.0 | 2.0 | 2.80 | 0.100 | No |
| **Driving Accuracy (%)** | 62.2 | 6.3 | 63.9 | 7.0 | 0.98 | 0.320 | No |

- Single Factor ANOVA Results ($p < .025$)
- No significant difference between groups for either:

Clubhead Speed or Driving Accuracy

# Clubhead Speed Hypothesis

A weak positive correlation was found (*r* = 0.14)

And Hi-HTV group mean was faster than Lo-HTV group

48.9 m/s to 48.0 m/s

But not enough to produce a significant difference between groups

Hypothesis is not Supported

Golfers with high HTV **DO NOT** have significantly higher clubhead speed at impact than low HTV golfers

Strength of Correlation as per Dancey and Reidy (2004)

# HTV and Clubhead Speed Discussion

- Possible speed gain
  - $v = \omega r$
  - Contact point is separated from rotation axis
- Nesbit (2005)
  - High gamma velocity of shaft can add 1.5m/s to the linear velocity of the clubhead at impact
- Cochran and Stobbs (1968)
  - Low HTV is a weaker swing because of the loss of the “screwdriver action”
- Hi-HTV group did have mean velocity 0.9m/s higher than the Lo-HTV group.
- But not enough for significance

# Driving Accuracy Hypothesis

A weak negative correlation was found ($r$ = -0.14)

And Lo-HTV group had slightly higher mean accuracy than Lo-HTV group

63.9% to 62.2%

But not enough to produce a significant difference between groups


Hypothesis is not Supported

Golfers with low HTV **DO NOT** have significantly better driving accuracy than high HTV golfers

Strength of Correlation as per Dancey and Reidy (2004)

# HTV and Driving Accuracy Discussion

- Cochran and Stobbs (1968) and Suttie (2011)
  - Both say high HTV less accurate due to greater chance of miss-timing contact
  - Their comments were only anecdotal; no data

- Our Results Disagree
  - We found both Hi-HTV and Lo-HTV produce similar driving accuracy

# Practical Application

- Instructors can teach either high or low HTV method with confidence that they both give acceptable results
- But must be consistent in body and arm actions as will be seen in Studies 2 and 3

# Study 2

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# Handle Twist Velocity

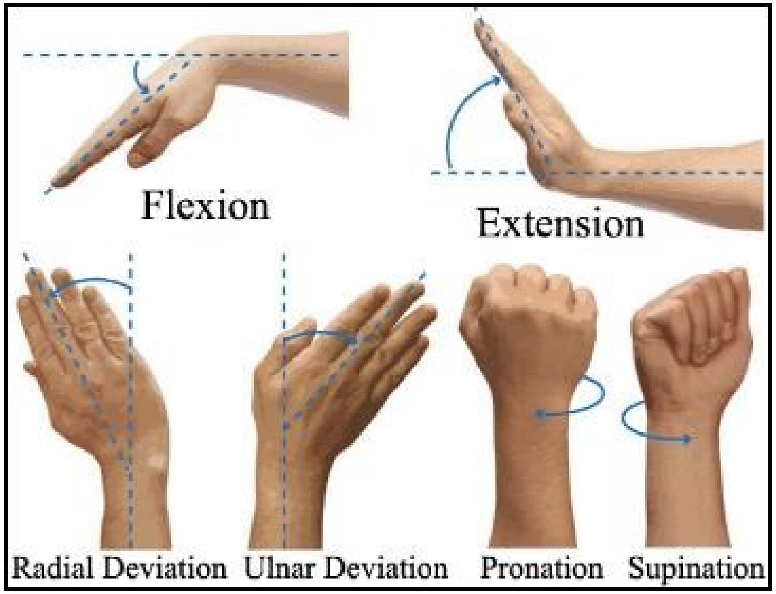
## Relationship to

# Lead Wrist Velocities

## and

# Trail Elbow Velocity

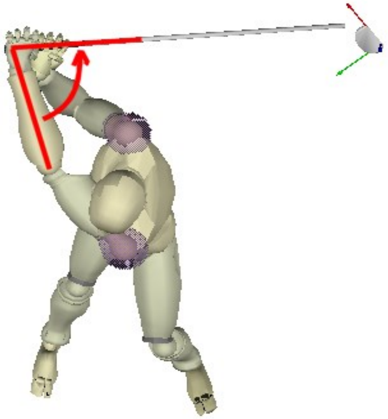
# Definitions




From: Mark Papas, www.revolutionarytennis.com

## Velocities at Impact

- **Lead Wrist Supination Velocity**
  - Rolling of forearm and wrist
- **Lead Wrist Extension Velocity**
  - Extension of lead wrist

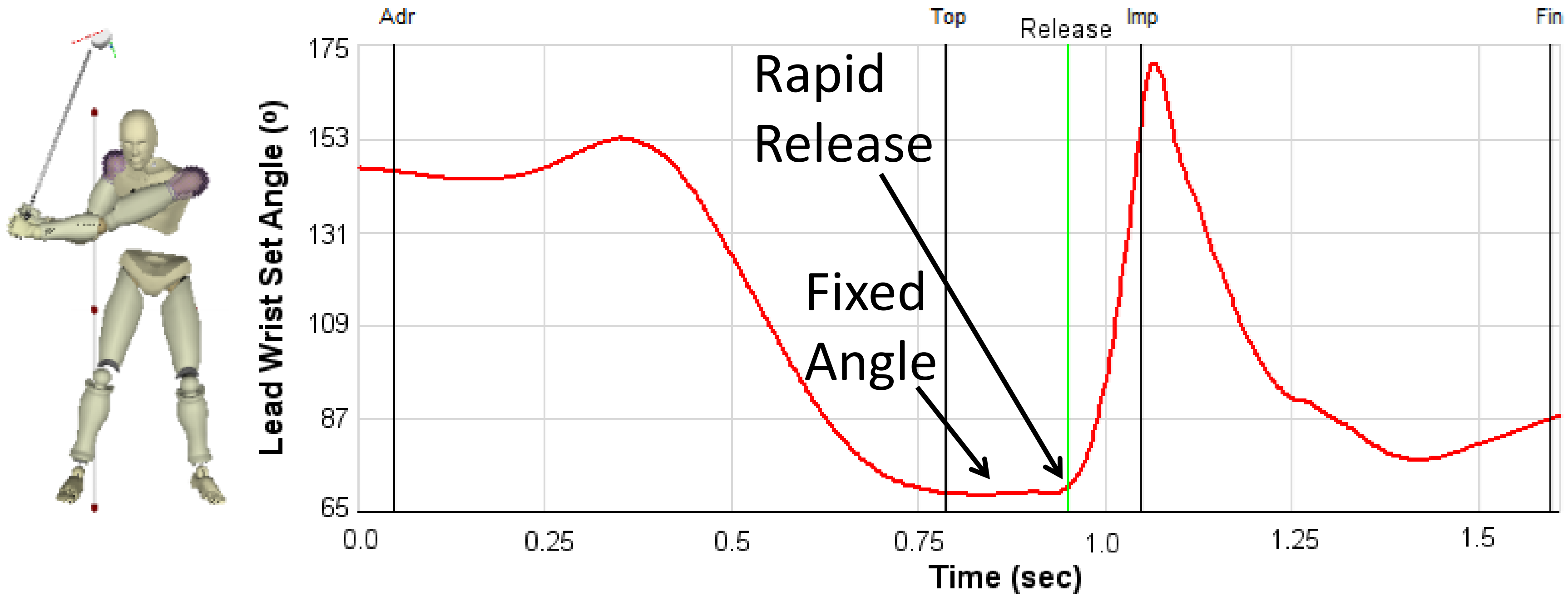


Lead Wrist Set Angle

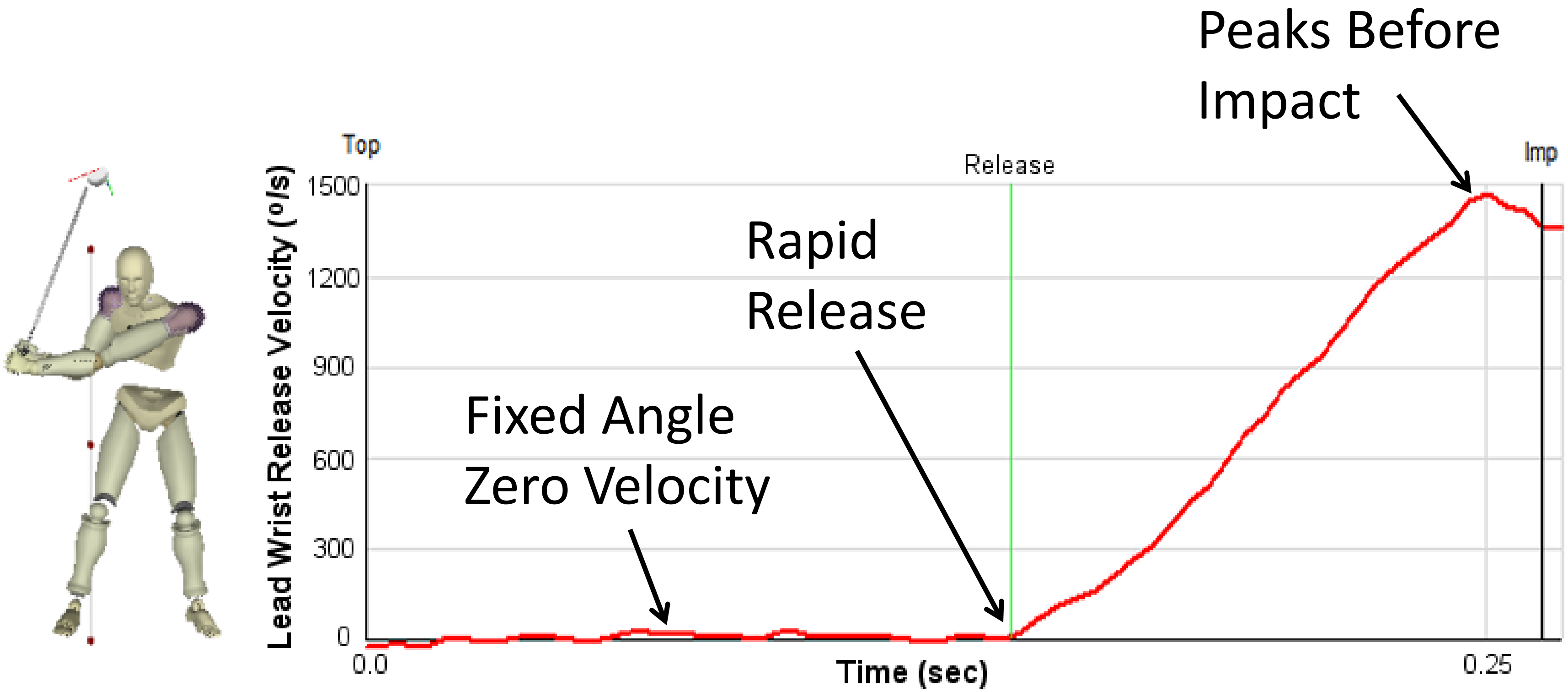
## Velocities at Maximum

- **Lead Wrist Ulnar Deviation Velocity**
  - Lateral motion of the wrist
- **Lead Wrist Release Velocity**
  - Angle between forearm and club shaft
- **Trail Elbow Extension Velocity**
  - Back elbow extending

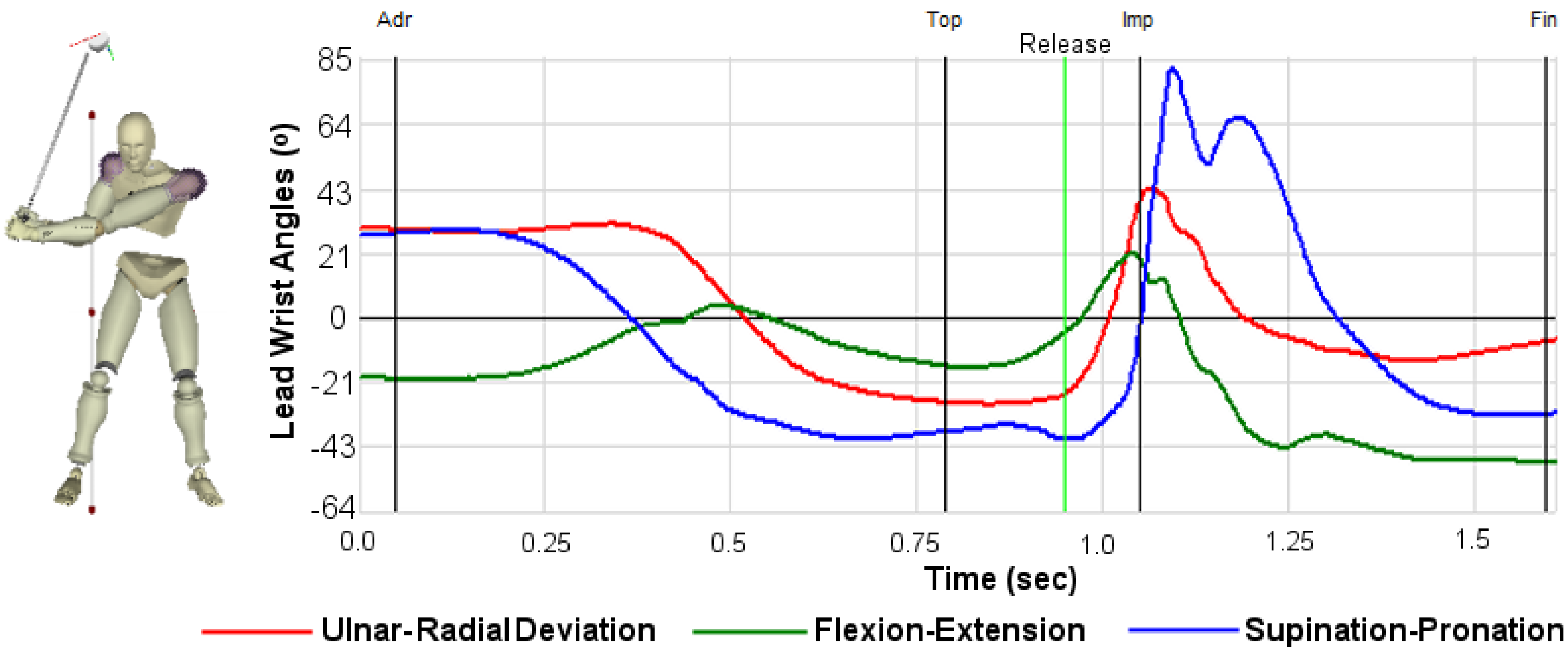
# Lead Wrist Set Angle



# Lead Wrist Release Velocity



# Lead Wrist Angle 3DOF Components

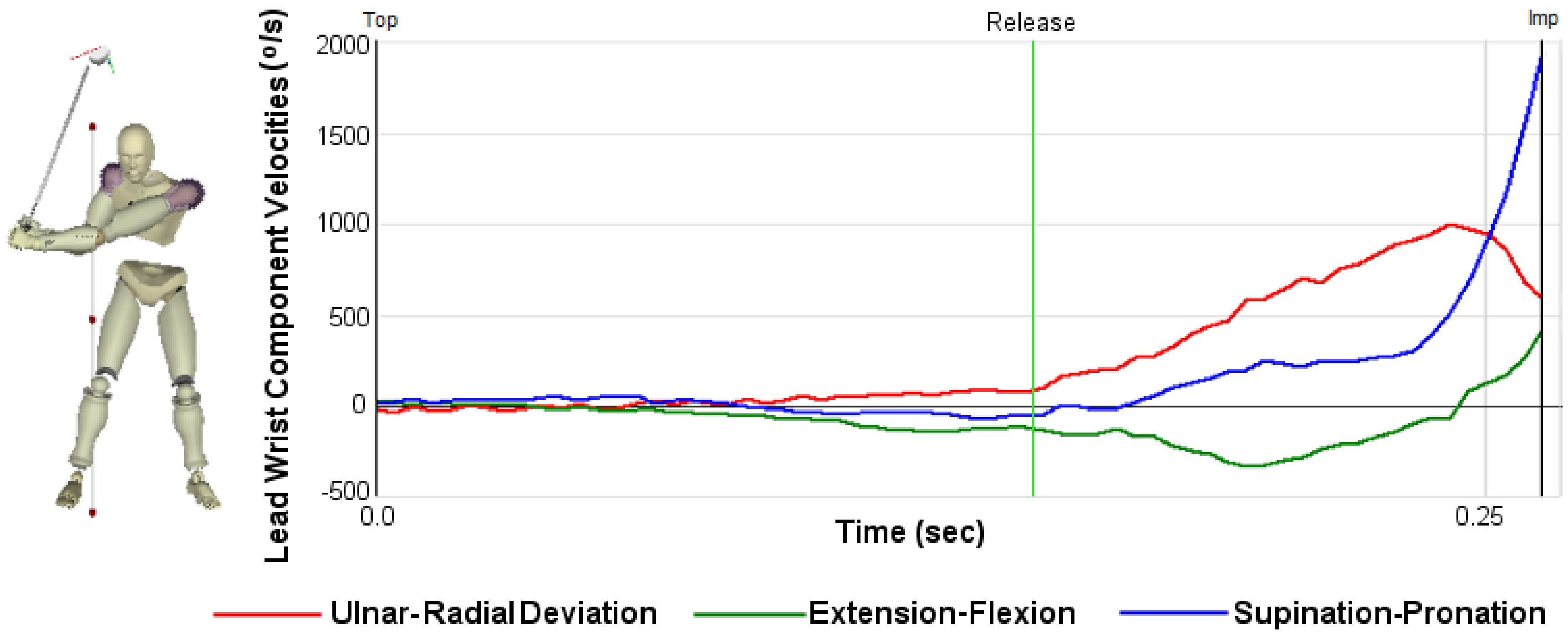



**Top**
- Radial Dev.
- Extended
- Pronated

**Downswing**
- Flexion
- Extra Pronation
- Ulnar Dev.
- Supination

**Impact**
- Ulnar Dev.
- Flexed
- Supinated

# Lead Wrist Release
# 3DOF Component Velocities




- Ulnar Velocity Peaks Before Impact
- Extension Velocity At Impact
- Supination Velocity is Largest at Impact

# Study 2: HYPOTHESES

**Lead Wrist Supination Velocity at Impact**

Will show positive correlation with HTV and
Hi-HTV group will be significantly faster than Lo-HTV group

**Lead Wrist Extension Velocity at Impact**

Hi-HTV group will be significantly faster than Lo-HTV group

**Lead Wrist Ulnar Deviation Velocity at Maximum**

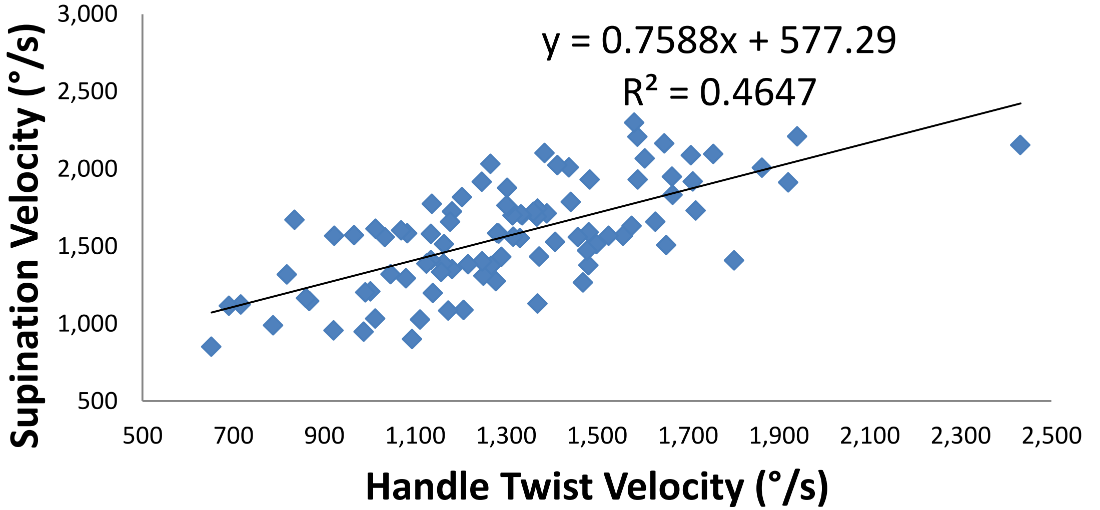
**Lead Wrist Release Velocity at Maximum**

**Trail Elbow Extension Velocity at Maximum**

Will show no significant difference between groups

# Descriptive Statistics and Correlation with HTV

| Angular Velocity | Mean (°/s) | SD (°/s) | *r* | $R^2$ | Strength |
|---|---|---|---|---|---|
| Lead Wrist Supination (Imp) | 1569 | 338 | 0.68 | 0.46 | Moderate |





Hypothesis is Supported

**Lead Wrist Supination Velocity at Impact**

Does show a moderate positive correlation with HTV

Strength of Correlation as per Dancey and Reidy (2004)

# ANOVAs with Hi-HTV v Lo-HTV

| Wrist/Elbow | Hi-HTV (°/s) | | Lo-HTV (°/s) | | | | Sig at |
|---|---|---|---|---|---|---|---|
| Angular Velocities | Mean | SD | Mean | SD | F[1,62] | *p* | *p* < .01 |
| Lead Wrist Supination (Imp) | **1811** | 286 | **1295** | 256 | 58.1 | **0.000** | **Yes** |
| Lead Wrist Extension (Imp) | **433** | 195 | **446** | 228 | 0.1 | **0.813** | No |
| Lead Wrist Ulnar Dev. (Max) | **922** | 126 | **859** | 180 | 2.6 | **0.109** | No |
| Lead Wrist Release (Max) | **1249** | 138 | **1186** | 180 | 2.5 | **0.119** | No |
| Trail Elbow Extension (Max) | **931** | 190 | **851** | 156 | 3.4 | **0.070** | No |

- Single Factor ANOVA Results ($p < .01$)
- Significant difference for **Lead Wrist Supination** with Hi-HTV > Lo-HTV
- No Significant difference for all the other tested velocities

# Study 2: Additional Hypothesis Results

Hypothesis is Supported

**Lead Wrist Supination Velocity at Impact**

Hi-HTV group IS significantly faster than Lo-HTV group

Hypothesis is not Supported

**Lead Wrist Extension Velocity at Impact**

Hi-HTV group IS NOT significantly faster than Lo-HTV group

Hypotheses are Supported

**Lead Wrist Ulnar Deviation Velocity at Maximum**

**Lead Wrist Release Velocity at Maximum**

**Trail Elbow Extension Velocity at Maximum**

Do show NO significant difference between groups

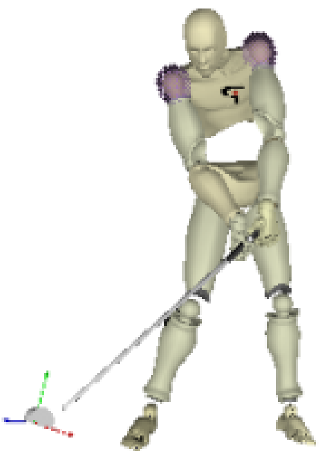
# Lead Wrist Supination Velocity at Impact Discussion

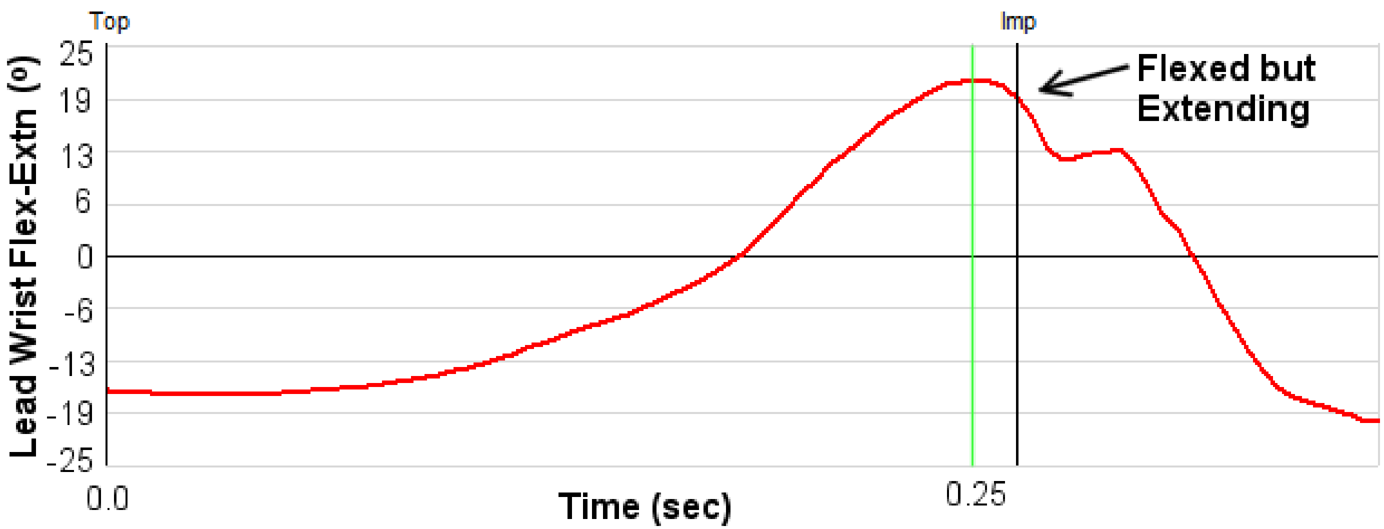
- Cochran and Stobbs (1968)
- MacKenzie and Sprigings (2009)
  - Both research groups state that it is the arm roll that twists the club handle and squares club face for impact
- Our data suggests this is true
  - Moderate Correlation between
    Lead Wrist Supination Velocity and HTV
  - Mean Hi-HTV Group 40% faster than Lo-HTV Group
    1811°/s v 1295°/s, certainly significant

# Lead Wrist Extension Velocity

- Hi-HTV Group not significantly faster
- 446°/s to 433°/s
- Interesting that these velocities are positive
- Means that Lead Wrist is Extending at Impact
- 92 of the 94 golfers in our database show this characteristic

# Lead Wrist Flexion-Extension






At Impact:
The lead wrist is in a **flexed position**
but has an **extending action**

# Study 3

-

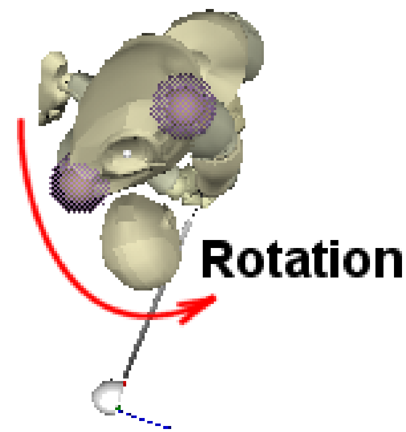
# Handle Twist Velocity

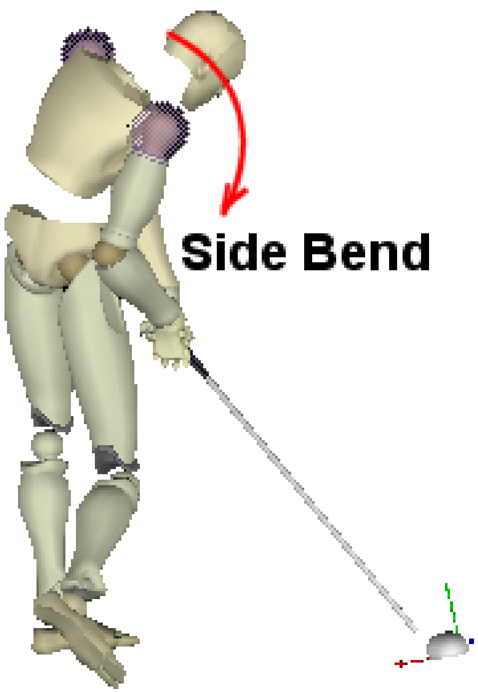
Relationship to

# Pelvis and Thorax Rotation and Side Bend

# Definitions

**Pelvis and Thorax Rotation at Impact**

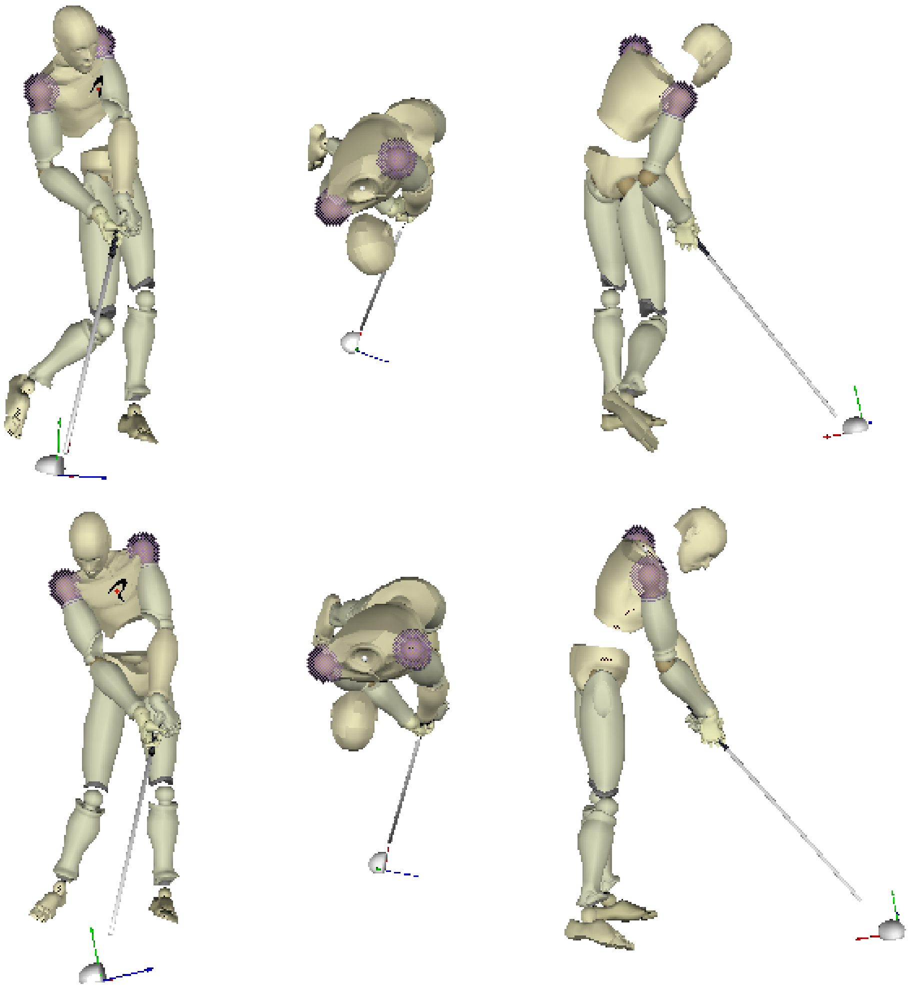



**Pelvis and Thorax Side Bend at Impact**

# What we Have Seen from 3D

- Low Handle Twist Velocity
- High Handle Twist Velocity



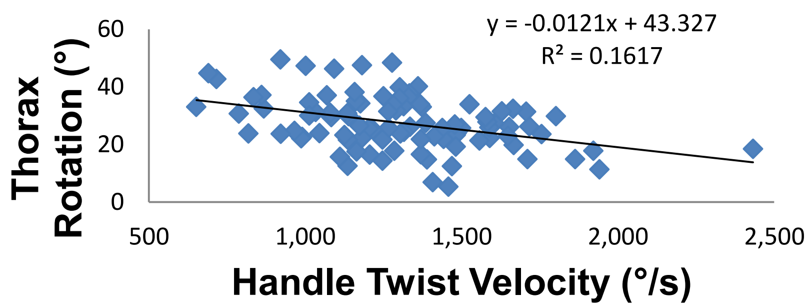
# Study 3: HYPOTHESES

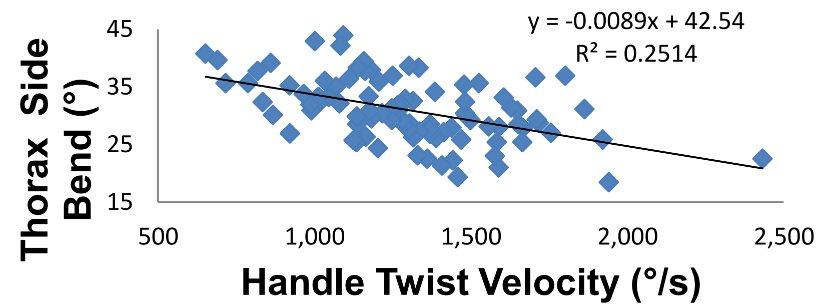
- **Pelvis and Thorax Rotation at Impact**
  Will show negative correlation with HTV and Lo-HTV group will be significantly more rotated open than Hi-HTV group

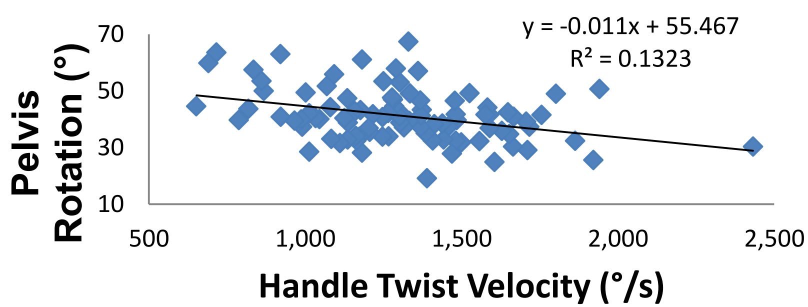
- **Pelvis and Thorax Side Bend at Impact**
  Will show negative correlation with HTV and Lo-HTV group will be significantly more side bent to trail side than Hi-HTV group

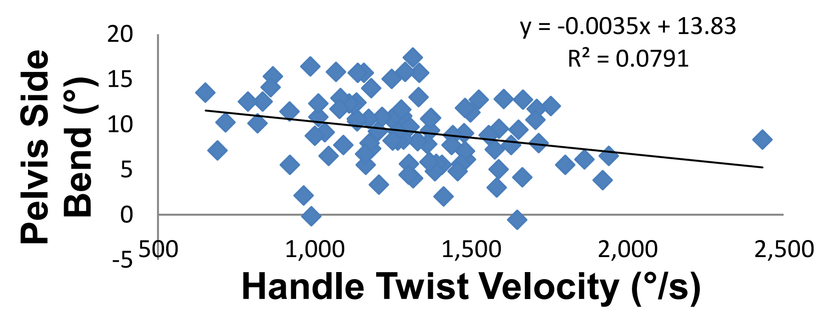
# Descriptive Statistics and Correlations with HTV

| | Mean (°) | SD (°) | *r* | $R^2$ | Strength |
|---|---|---|---|---|---|
| **Thorax Rotation (Open)** | 27 | 9 | -0.40 | 0.16 | Moderate |
| **Thorax Side Bend (Trail)** | 31 | 5 | -0.50 | 0.25 | Moderate |
| **Pelvis Rotation (Open)** | 41 | 9 | -0.36 | 0.13 | Weak |
| **Pelvis Side Bend (Trail)** | 9 | 4 | -0.28 | 0.08 | Weak |



# Study 3: Hypotheses are Supported

**Thorax Rotation and Side Bend at Impact**

Do show a moderate negative correlation with HTV

**Pelvis Rotation and Side Bend at Impact**

Do show a weak negative correlation with HTV

Strength of Correlation as per Dancey and Reidy (2004)

# ANOVAs with Hi-HTV v Lo-HTV

| Pelvis and Thorax Angles at Impact | Hi-HTV (°) | | Lo-HTV (°) | | | | Sig at |
|---|---|---|---|---|---|---|---|
| | **Mean** | **SD** | **Mean** | **SD** | **F[1,62]** | ***p*** | ***p* < .0125** |
| **Thorax Rotation (Open)** | **23** | 7 | **31** | 9 | 15.9 | **0.000** | **Yes** |
| **Pelvis Rotation (Open)** | **37** | 6 | **43** | 7 | 9.7 | **0.003** | **Yes** |
| **Thorax Side Bend (Trail)** | **28** | 5 | **34** | 5 | 27.1 | **0.000** | **Yes** |
| **Pelvis Side Bend (Trail)** | **8** | 3 | **11** | 4 | 10.2 | **0.002** | **Yes** |

- Single Factor ANOVA Results ($p < .0125$)
- Significant difference for all body angles with Lo-HTV > Hi-HTV

# Study 3: Hypotheses are Supported

**Pelvis and Thorax Rotation at Impact**
Lo-HTV group is significantly more rotated open than Hi-HTV group

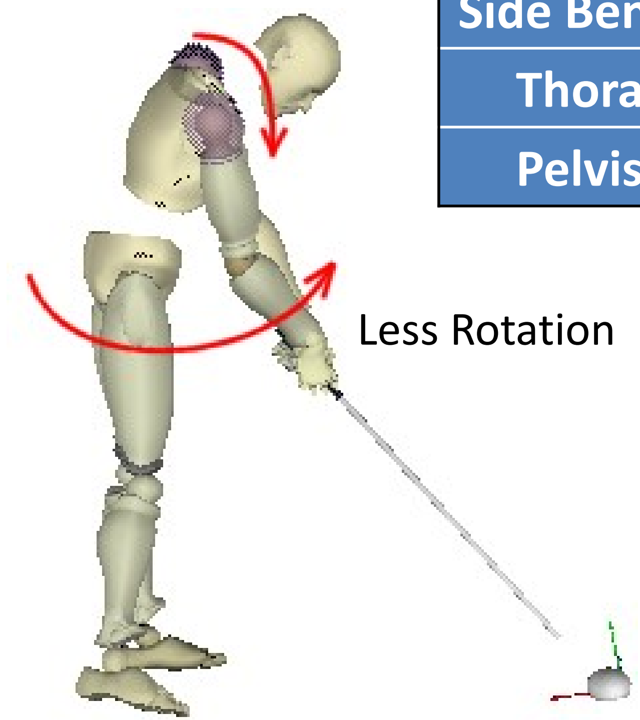
**Pelvis and Thorax Side Bend at Impact**
Lo-HTV group is significantly more side bent to trail side than Hi-HTV group

# HTV with Rotation and Side Bend Discussion

| | Hi-HTV | Lo-HTV |
|---|---|---|
| **Rotation (Open)** | | |
| **Thorax** | **23°** | **31°** |
| **Pelvis** | **37°** | **43°** |
| **Side Bend (Trail)** | | |
| **Thorax** | **28°** | **34°** |
| **Pelvis** | **8°** | **11°** |

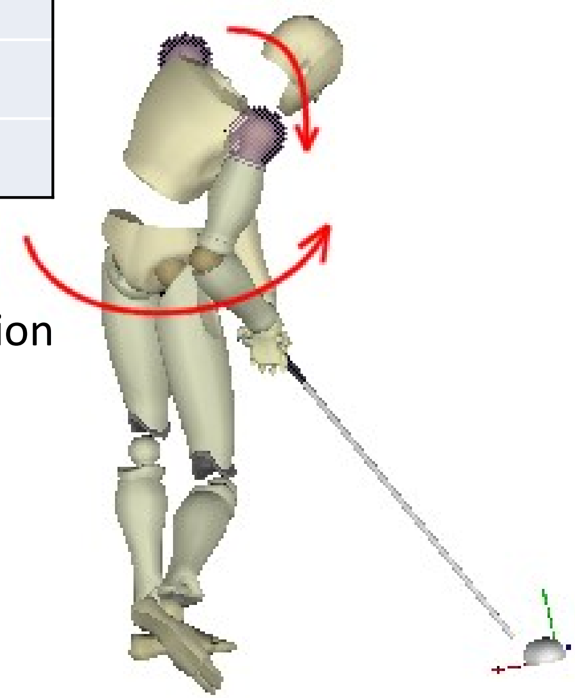
Hi-HTV

Less Side Bend




Lo-HTV

More Side Bend



More Rotation

# Instructional Literature

| Cochran and Stobbs (1968) | | Suttie (2011) |
|---|---|---|
| • Rollers<br>– Use Arms More<br>– Roll Club Rapidly<br>– Less Body Action | Hi-HTV | • Open-Face Method<br>– Active Closing of Club Face<br>– “Handsy” Swing<br>– Medium to Slow Hip Speed |
| • Pushers<br>– Less Arm Action<br>– Use Body More<br>– Rotate Body Faster | Lo-HTV | • Closed-Face Method<br>– Less Twist of the Club needed<br>– Faster Hips Needed<br>– More Open at Impact |

# Other Studies - Rotation Values

| Rotation Angle | Type | Pelvis | Thorax | Skill Level |
|---|---|---|---|---|
| **Cheetham** | Hi-HTV | 37° | 23° | Tour Pro |
| | Lo-HTV | 43° | 31° | Tour Pro |
| **McTeigue et al.** | PGA Male | 32° | 26° | Tour Pro |
| | PGA Senior | 34° | 28° | Senior Pro |
| | Amateur | 35° | 27° | Amateur |
| **Myers et al.** | Hi Vel | 38° | 25° | Amateur |
| | Med Vel | 35° | 23° | Amateur |
| | Lo Vel | 29° | 20° | Amateur |
| **Horan et al.** | Male | 44° | 26° | Skilled |
| | Female | 50° | 29° | Skilled |

- All are open at impact with both pelvis and thorax
- Pelvis is more open than thorax
- None are close to square at impact. So definitely not same as at address

# Practical Applications

# New Instructional Information

- Valuable to know what the elite players do
- Both handle twist techniques can be successful
- Rolling the arms more in the downswing will increase handle twist velocity and clubhead closing velocity
- Lead wrist is extending at impact

- Important to be consistent in teaching the wrist and body characteristics that match
  – Don't force a high HTV golfer to be more open and side bent at impact
  – Unless you also change their arm and club twist action

# New High Quality Databases

- Now have several high quality databases of the best golfers in the world with full-body motion capture data
  - 94 PGA and European Tour Golfers
  - 32 High HTV PGA and European Tour Golfers
  - 32 Low HTV PGA and European Tour Golfers
  - 51 PGA Tour Winners
- Quality data for future studies and education

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**Thank You**

# Thank You