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BIOMECHANICS

INTRODUCTION TO BIOMECHANICS

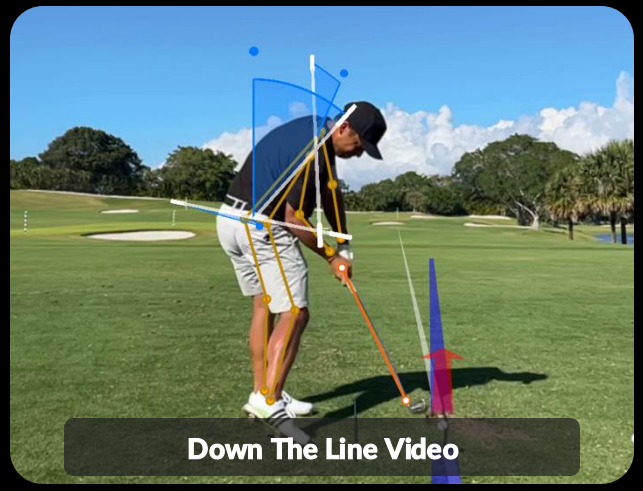
Chapter 1: 3D Motion Analysis

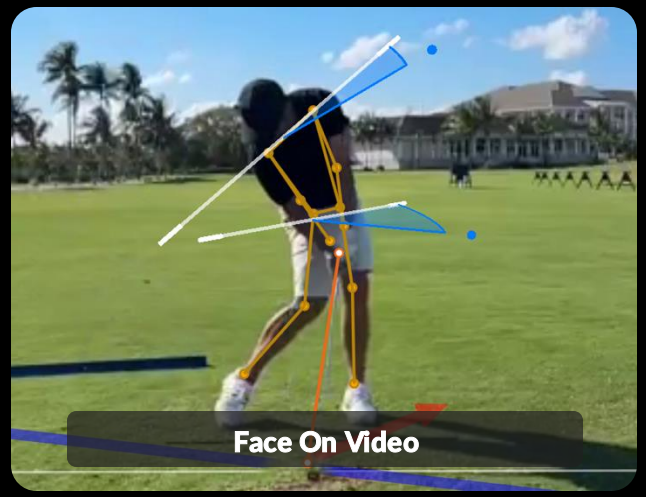
Introduction

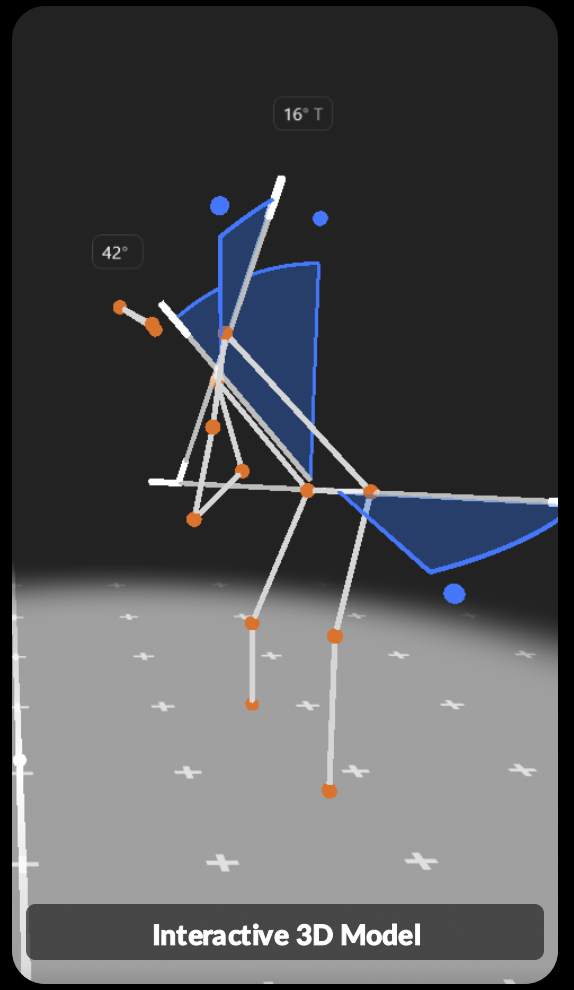
LEARNING OBJECTIVES FOR BIOMECHANICS

By the end of this module, you should be able to:

- ✓ **Explain biomechanics in golf performance** and its role in linking body, club, and ball.
- ✓ **Describe and measure motion in 3D**, including the 6 degrees of freedom and global vs. local coordinate systems.
- ✓ **Identify and analyze key body segments** (pelvis, upper torso, head, stance, posture) using Trackman 3D Motion Analysis.
- ✓ **Apply biomechanics in coaching**, connecting body motion to club delivery and ball flight, and communicating concepts through clear player cues.







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Introduction

WHAT IS BIOMECHANICS IN GOLF PERFORMANCE?

Biomechanics is the study of how the body moves and produces performance.

To understand it in golf, we can think in three parts:

- ✓ **Structure:** The setup and alignment of the body
- ✓ **Function:** How the body delivers the club and creates ball flight
- ✓ **Motion:** The analysis of how the body and club move through space

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Introduction

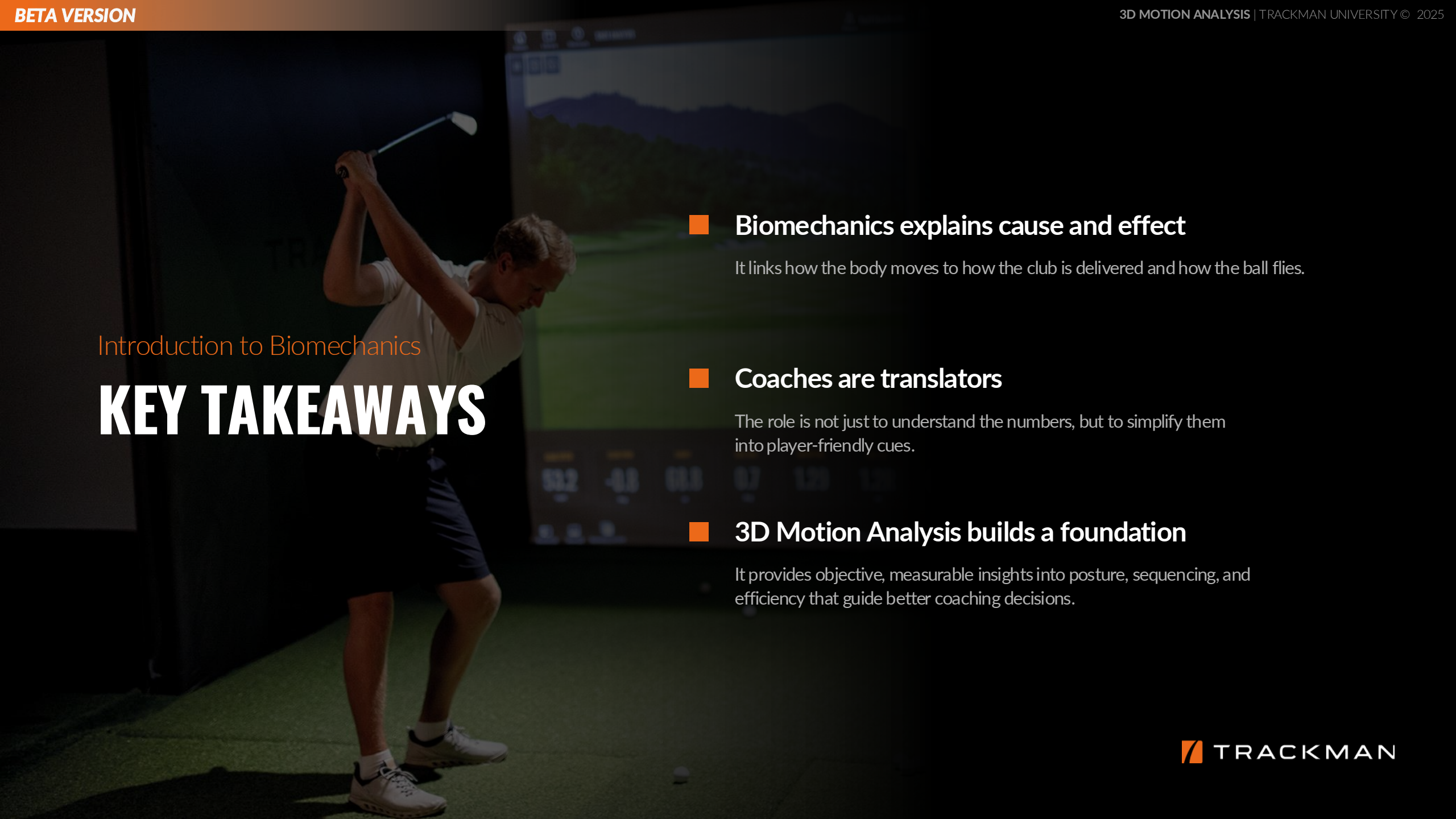
UNDERSTAND MOVEMENT
COMMUNICATE FEELINGS

Coaches can benefit from learning how to simplify 3D concepts for players using feel-based cues tied to objective data.

The cues can be either internal (focus on the body itself) or external (focus on the effect or environment).

- ✓ **Internal cues:** How the body parts move: e.g. keep your arm straight
- ✓ **External cues:** What the club or ball should do: e.g. brush the grass after the ball

Use visual tools and simplified language to help bridge the gap between data and execution.



Introduction to Biomechanics

KEY TAKEAWAYS

Biomechanics explains cause and effect

It links how the body moves to how the club is delivered and how the ball flies.

Coaches are translators

The role is not just to understand the numbers, but to simplify them into player-friendly cues.

3D Motion Analysis builds a foundation

It provides objective, measurable insights into posture, sequencing, and efficiency that guide better coaching decisions.

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FUNDAMENTAL PRINCIPLES OF BIOMECHANICS

Chapter 2: A Scientific Foundation

Fundamental Principles of Biomechanics

KINEMATICS & KINETICS

Kinematics

What the motion looks like

- ✓ Position
- ✓ Direction
- ✓ Speed
- ✓ Acceleration

Kinetics *

Why the motion happens

- ✓ Forces
- ✓ Torque
- ✓ Ground reaction forces

** Kinetic measurement are not part of 3D Motion Analysis*

Club Speed (kinematics) comes from Ground Forces (kinetics)

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Fundamental Principles of Biomechanics

NEWTON'S LAWS IN GOLF

Law of Inertia

A body at rest stays at rest, and a body in motion stays in motion unless acted on by an outside force.

A golfer's setup posture remains stable until they initiate motion — poor balance leads to unwanted sway.

Law of Acceleration

The more force you apply, the faster the club or ball accelerates.

A heavier club (mass) requires more effort to achieve the same acceleration.

Force = Mass x Acceleration

Law of Action-Reaction

For every action, there is an equal and opposite reaction.

At impact, the club exerts force on the ball, and the ball exerts equal and opposite force on the club (felt as vibration/feedback).

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Fundamental Principles of Biomechanics

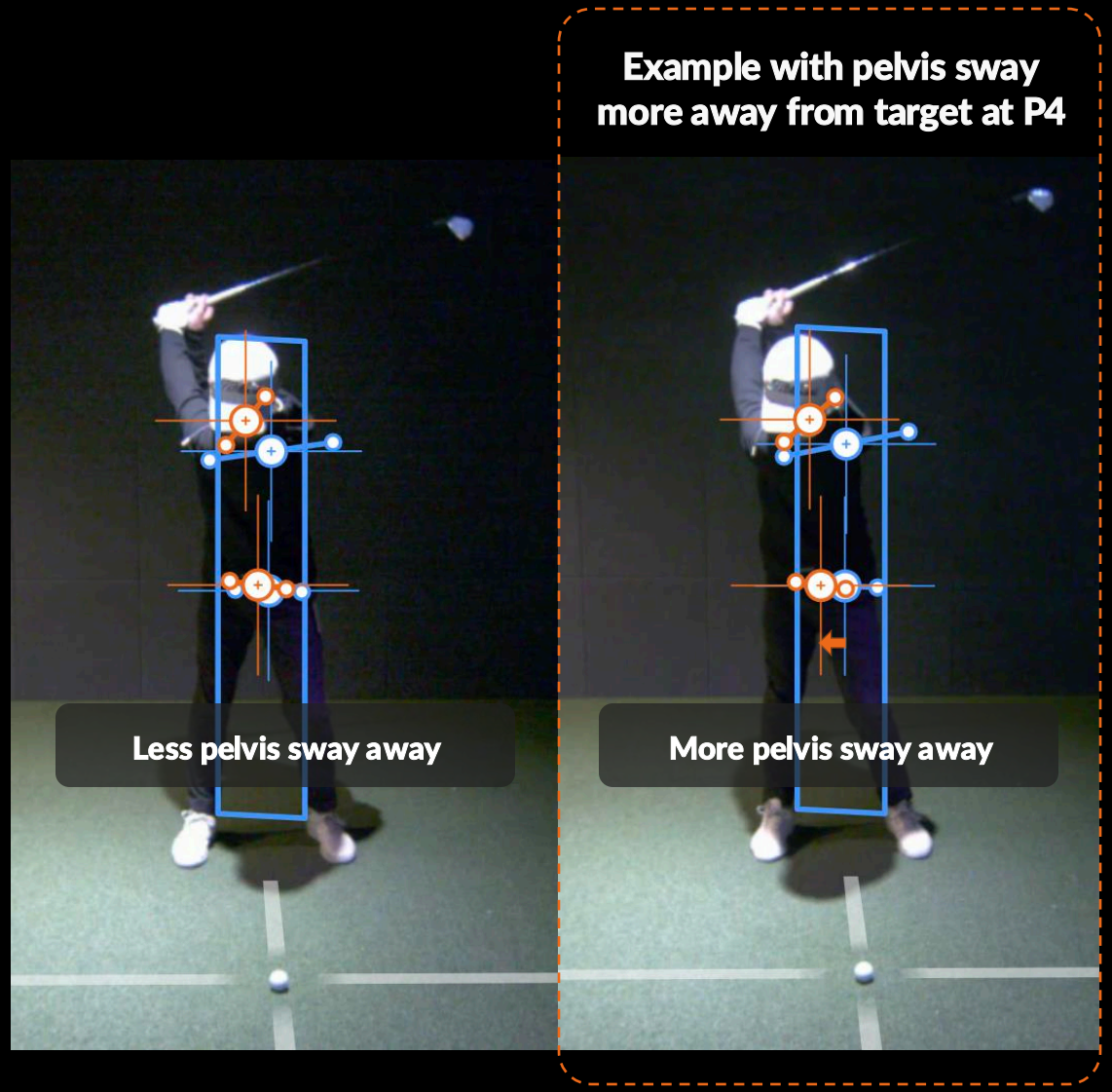
BALANCE AND STABILITY SUPPORT MORE REPEATABLE MOTION

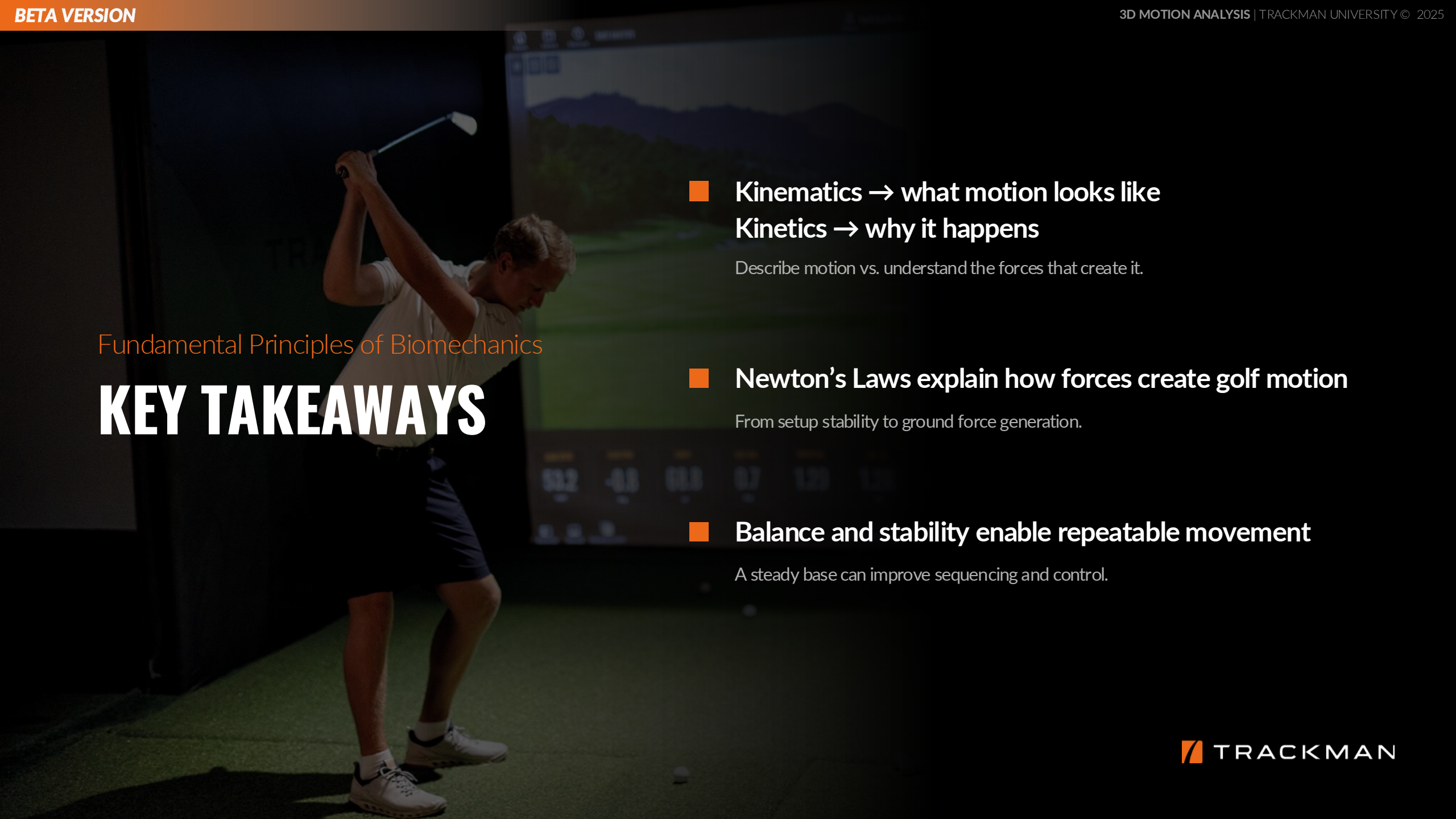
Balance is keeping your weight evenly controlled so you don't fall or sway.

Stability the ability to stay steady when forces act on you (like swinging a club).

Center of Mass (CoM) * is the point where your body weight is balanced. If it moves outside your stance, you lose stability.

** Center of Mass (CoM) is not included in 3D Motion Analysis, and only mentioned for educational purposes.*





Fundamental Principles of Biomechanics

KEY TAKEAWAYS

- **Kinematics → what motion looks like**
  Kinetics → why it happens
  Describe motion vs. understand the forces that create it.
- **Newton's Laws explain how forces create golf motion**
  From setup stability to ground force generation.
- **Balance and stability enable repeatable movement**
  A steady base can improve sequencing and control.

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TRACKING JOINTS & BODY SEGMENTS

Chapter 3: A Technical Perspective

Tracking Joints & Body Segments

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HOW 3D JOINT TRACKING WORKS

Trackman's 3D Motion Analysis uses two synchronized cameras to track the center of each joint, to represent the "stickman" of the player.

By triangulating the joint from both camera views, the exact 3D position can be calculated for every frame.

The cameras are calibrated to the Trackman target line, meaning body motion data is aligned with the same coordinate system as club and ball tracking.

This creates one unified performance model that links body motion directly to delivery and ball flight.

3D Motion Analysis works for both TM4 and TMiO

Tracking Joints & Body Segments

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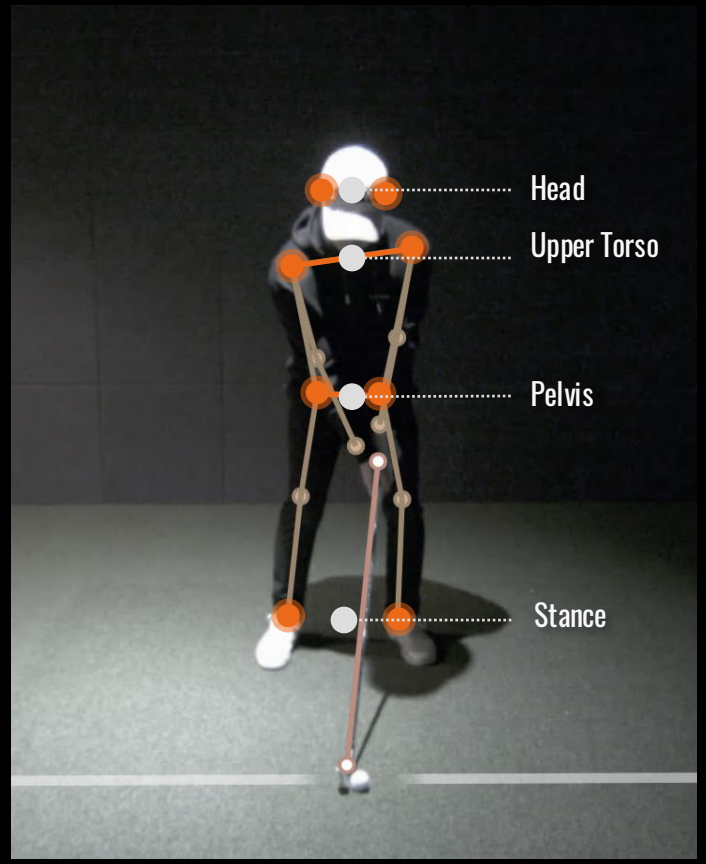
TRACKING MAJOR JOINTS AND BODY SEGMENTS AT SETUP AND IN MOTION

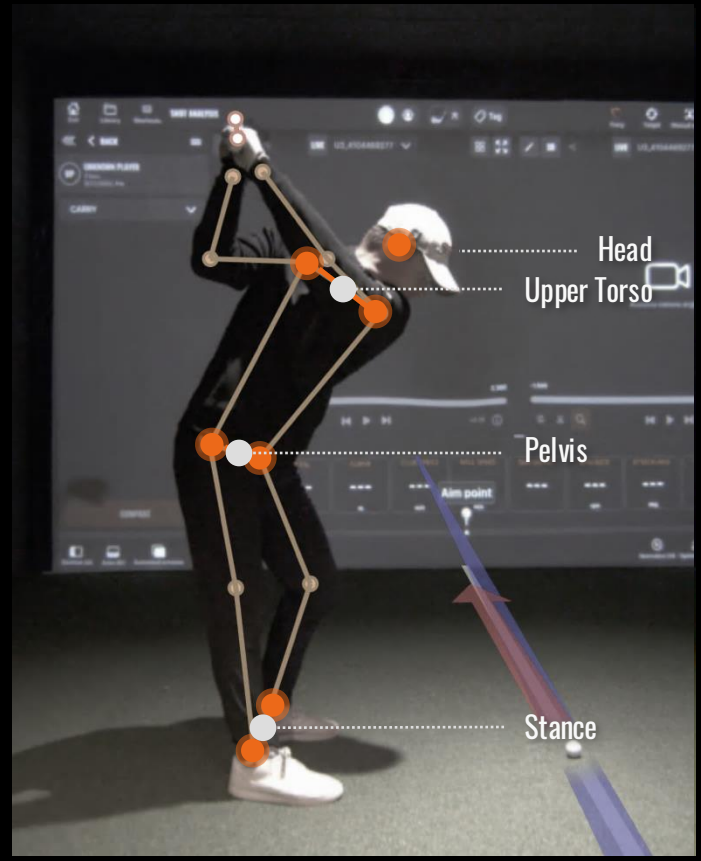
By analyzing how each segment moves and interacts with others, we can observe the sequence of motion that drives speed, consistency, and control.

Each joint plays a different role, and tracking these joints helps us understand how the body produces power and where inefficiencies or compensations might happen.

With Trackman 3D Motion Analysis, you can measure the movement of key body segments:

- ✓ Head
- ✓ Upper Torso
- ✓ Pelvis
- ✓ Stance
- ✓ Arms and hands (coming soon)





Tracking Joints & Body Segments

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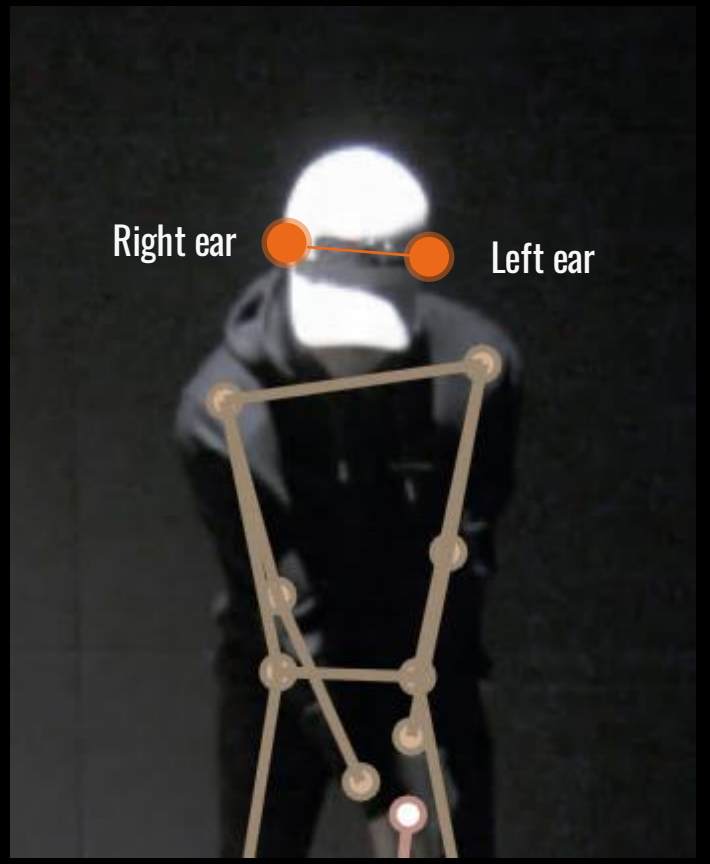
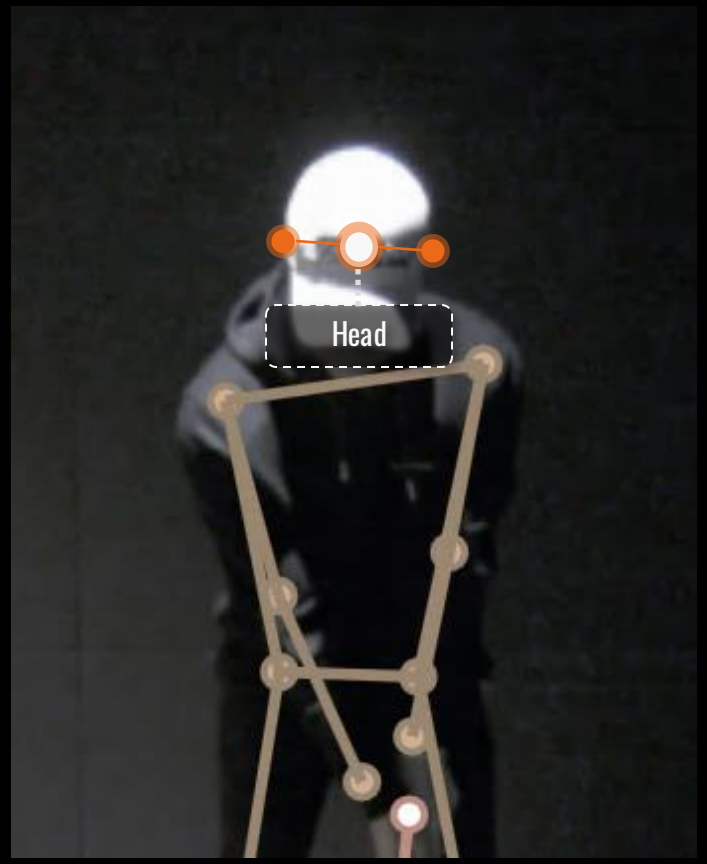
THE HEAD





The head is referenced as the midpoint between the ears

Tracking the head provides insight into both linear and rotational movements:

- **Rotations** (turn, tilt and bend)
- **Translations** (side-to-side, forward-back, and up-down movement)

Head movement is a key reference for posture control, swing consistency, and player balance throughout the motion.

Tracking Joints & Body Segments

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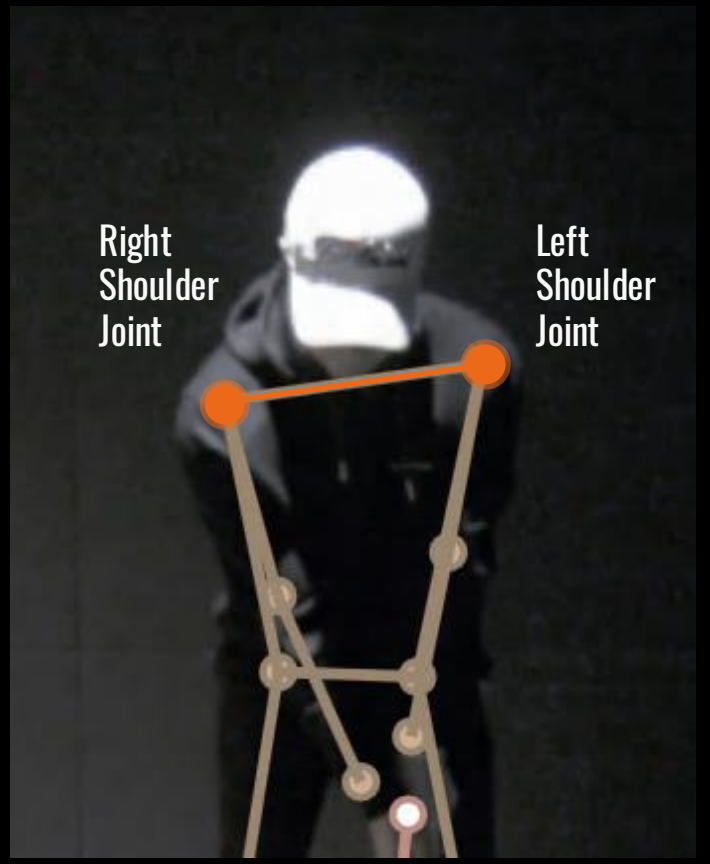
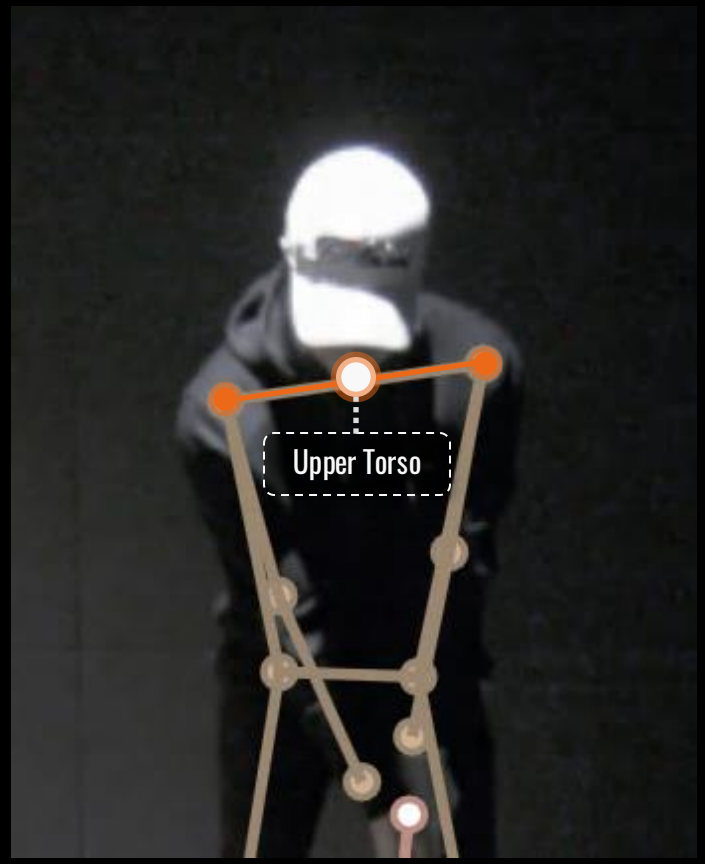
THE UPPER TORSO





The upper torso is referenced as the midpoint between the shoulder joints

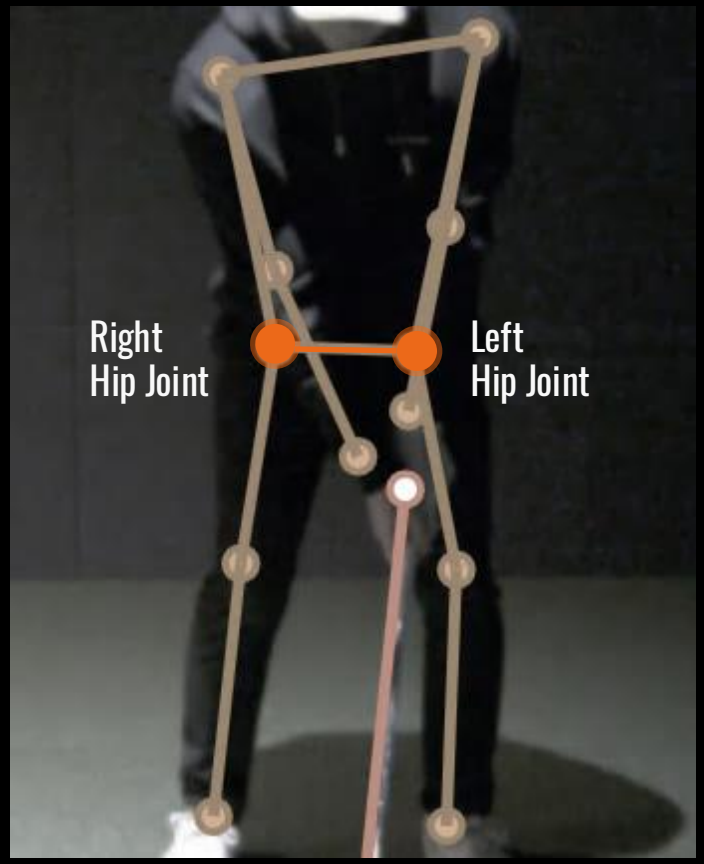
It serves as a key reference for measuring:

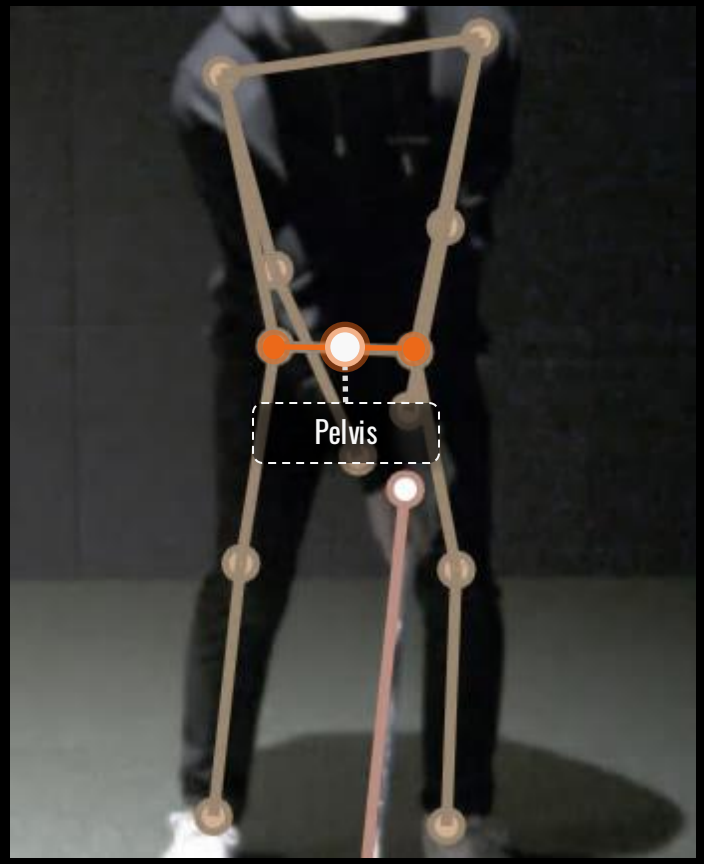
- **Alignment** relative to the target line
- **Rotations** (turn, tilt and bend)
- **Translations** (side-to-side, forward-back, and up-down movement)

Tracking the upper torso allows coaches to analyze shoulder line direction, rotational sequencing, and posture control throughout the swing.

Tracking Joints & Body Segments

THE PELVIS





The pelvis is referenced as the midpoint between the hip joints

It provides a stable base for body motion and is measured for:

- **Alignment** at setup
- **Rotations** (turn, tilt and bend)
- **Translations** (lateral sway, thrust, and lift)

The pelvis plays a central role in generating power, sequencing movement, and maintaining balance. Its position and rotation strongly influence club path, swing direction, and overall efficiency.

Tracking Joints & Body Segments

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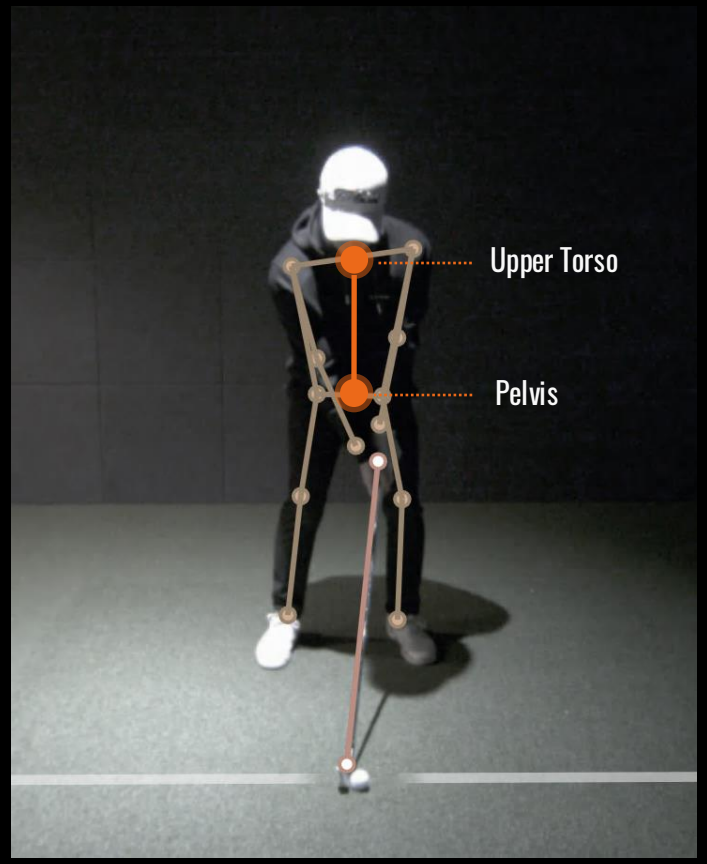
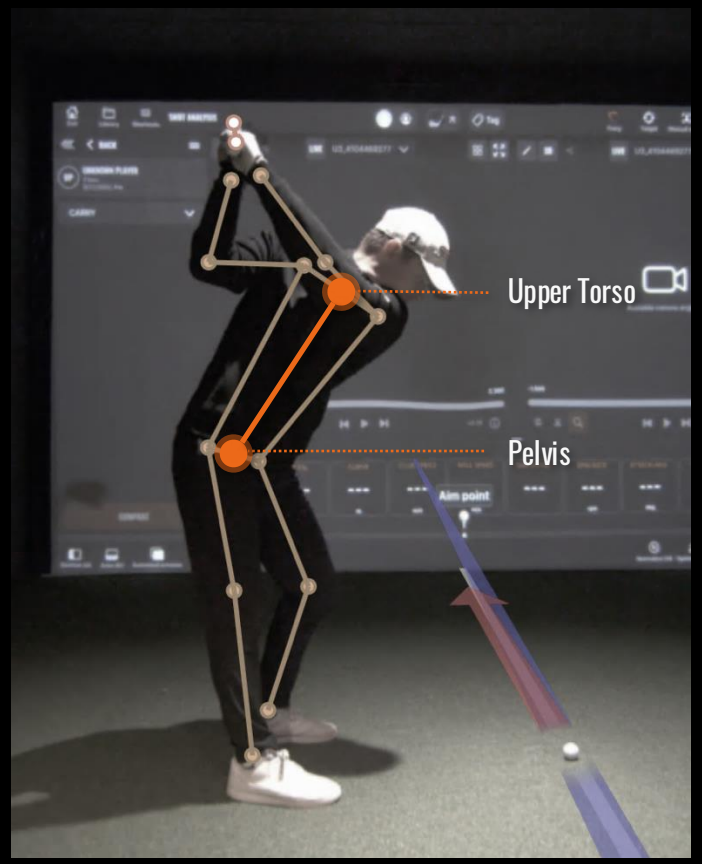
THE SPINE ANGLE FOR POSTURE





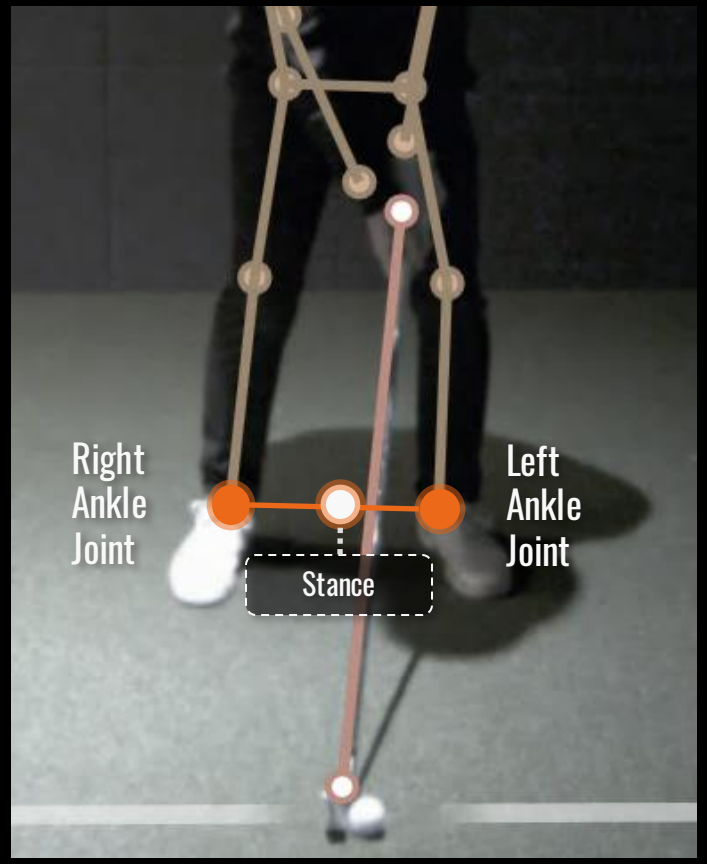
The spine angle is estimated by connecting the midpoint of the upper torso with the pelvis

This straight-line reference describes how the upper torso bends forward and tilts sideways at setup, and how this movement changes throughout the swing.

In Trackman parameters, this is referred to as Posture. While the actual spine is curved, this simplified model provides a consistent and measurable reference for motion analysis.

Tracking Joints & Body Segments

THE STANCE

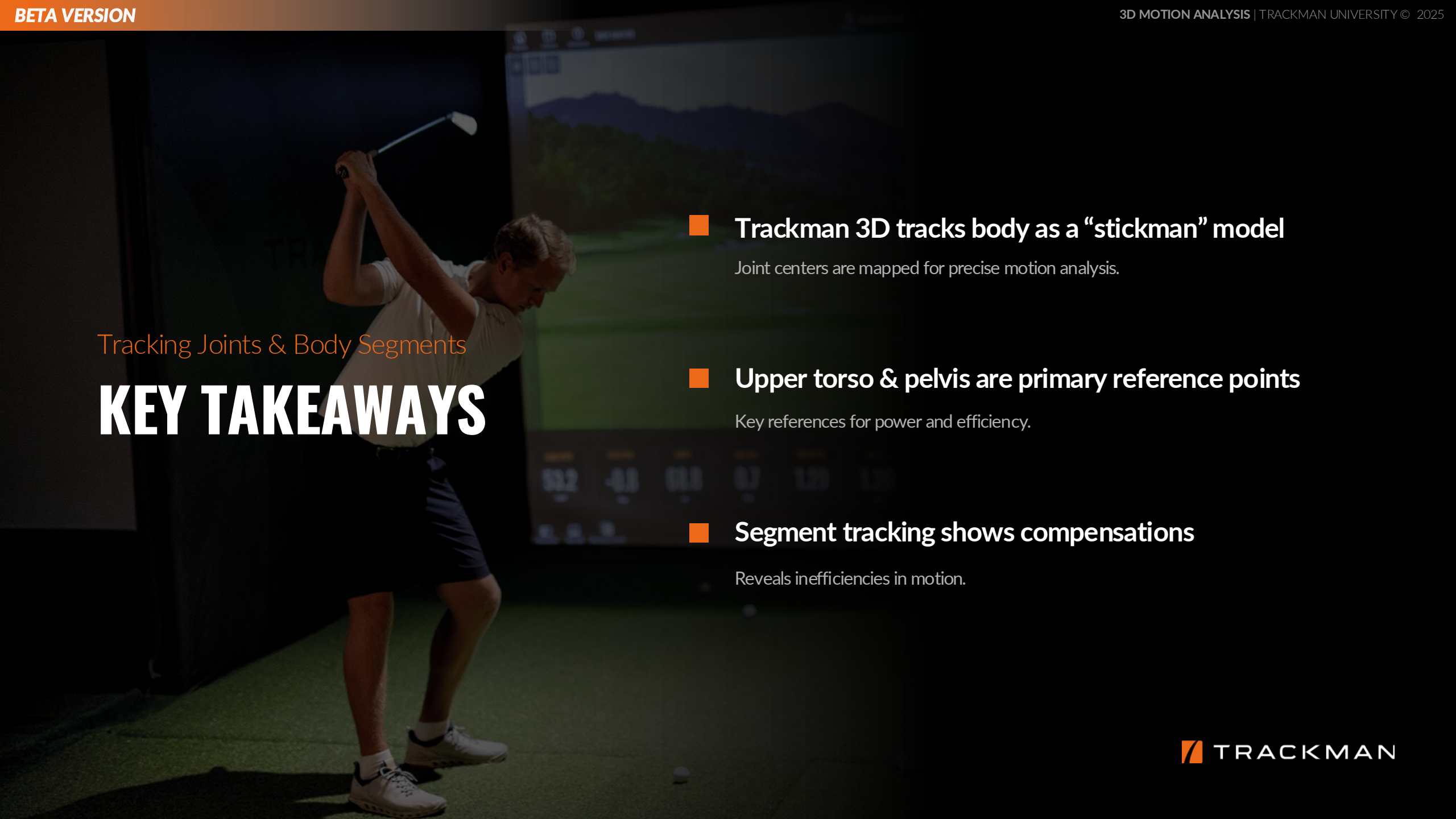


The stance is referenced as the midpoint between the ankle joints – seen perpendicular from the target line

It sets the foundation for posture, alignment, and balance, and is measured for:

- **Alignment** relative to the target line
- **Stance width** to balance stability and mobility
- **Depth** (distance from the ball) to influence swing plane
- **Ball Position** to control low point and attack angle

A consistent stance provides the base for repeatable motion, efficient sequencing, and accurate club delivery.



Tracking Joints & Body Segments

KEY TAKEAWAYS

- **Trackman 3D tracks body as a “stickman” model**

  Joint centers are mapped for precise motion analysis.

- **Upper torso & pelvis are primary reference points**

  Key references for power and efficiency.

- **Segment tracking shows compensations**

  Reveals inefficiencies in motion.

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DEFINITIONS FOR COORDINATE SYSTEMS

Chapter 4: Descriptions and References

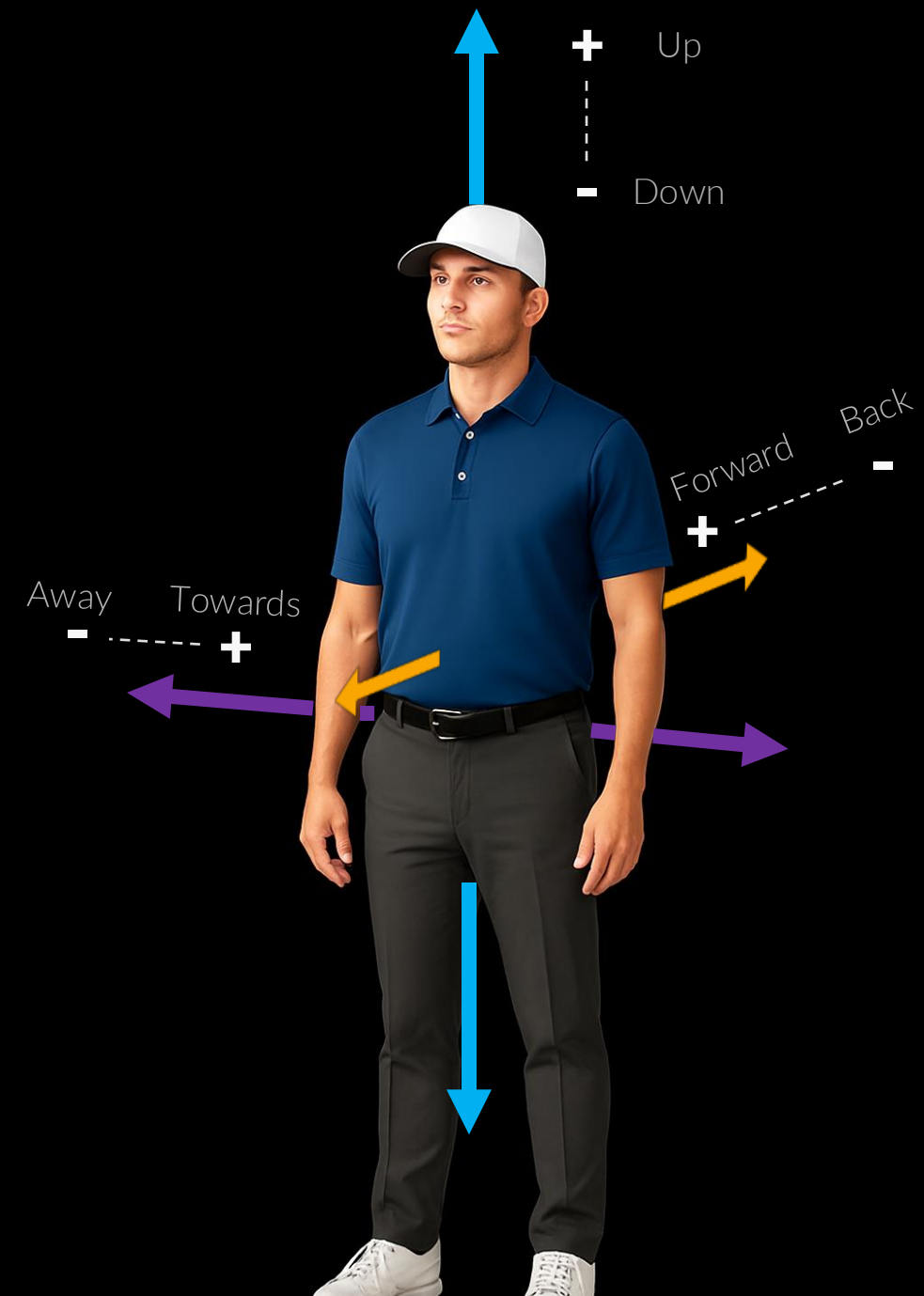
Definitions & Coordinate Systems

THE PLANES AND AXES USED TO REFERENCE HUMAN MOTION IN 3D

Body motion in 3D is defined on 3 planes, but 3D Motion Analysis data is shown relative to three main axes along the planes:

- Forward–Back
- Side-to-Side
- Up–Down

Each axis allows for movement along it (translation) and rotation around it, creating the six degrees of freedom (6DOF) that describe human motion.



- Forward-Back
- Side-to-side
- Up-Down

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Definitions & Coordinate Systems

BODY MOTION EXPLAINED IN 3D

In golf, the motions are expressed as translations (sway, thrust, lift) and rotations (bend, tilt, and turn). Together, they provide the foundation for analyzing body movement and linking it to club delivery and ball flight.

Body Motions Along an Axis (3DOF) → Translations (Linear)

- Side-to-Side Axis → Sway
- Front–Back Axis → Thrust
- Up–Down Axis → Lift

Measurements: Distance (inches, feet, meters)
Zero reference: Target, ground and vertical

Body Rotations Around an Axis (3DOF) → Rotations (Angular)

- Side-to-Side Axis → Bend
- Front–Back Axis → Tilt
- Up–Down Axis → Turn

Measurement: Angles (degrees)
Zero reference: Body segment's position at P1

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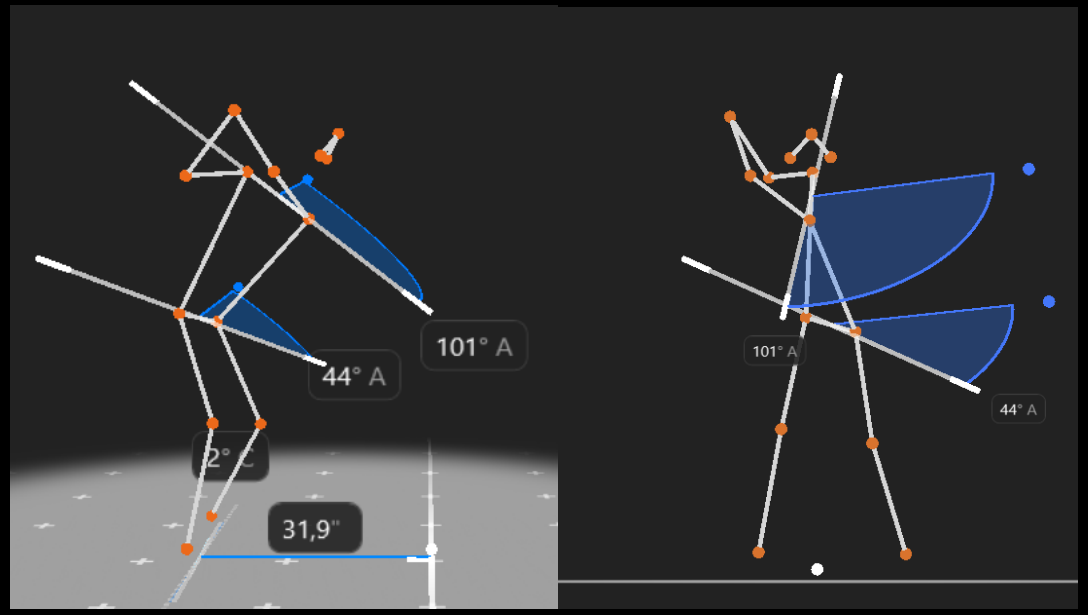
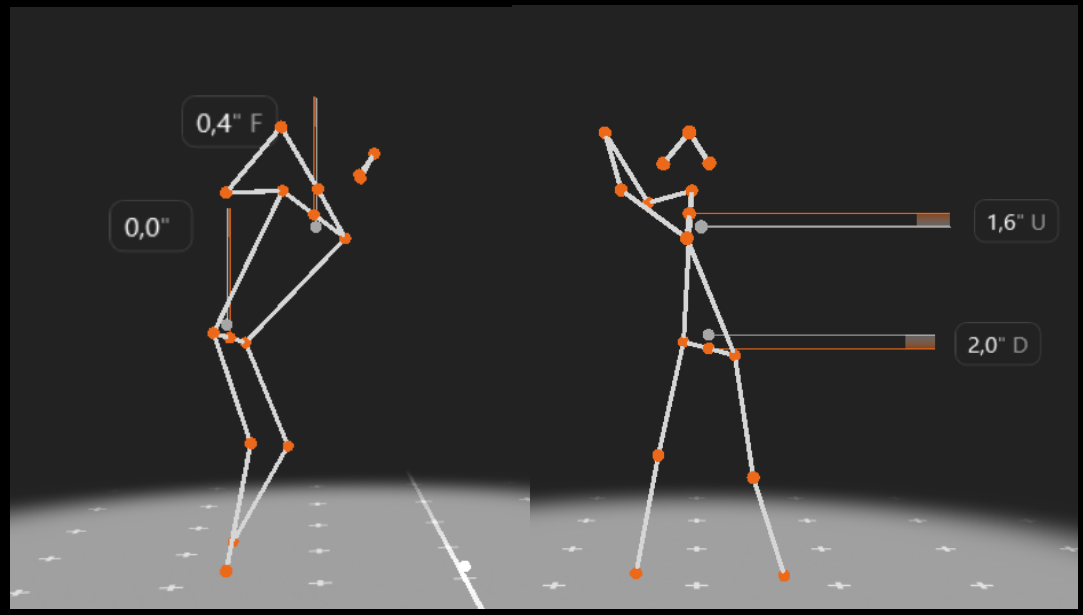
Definitions & Coordinate Systems

INTRODUCTION TO GLOBAL AND LOCAL COORDINATE SYSTEMS





Global Coordinates

- Using the world - the target, ground or vertical as the zero reference.
- Applies to alignment and angular motion (rotations).

Local Coordinates

- Using the body's position at P1 as the zero reference.
- Applies to linear motion (translations).

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Definitions & Coordinate Systems

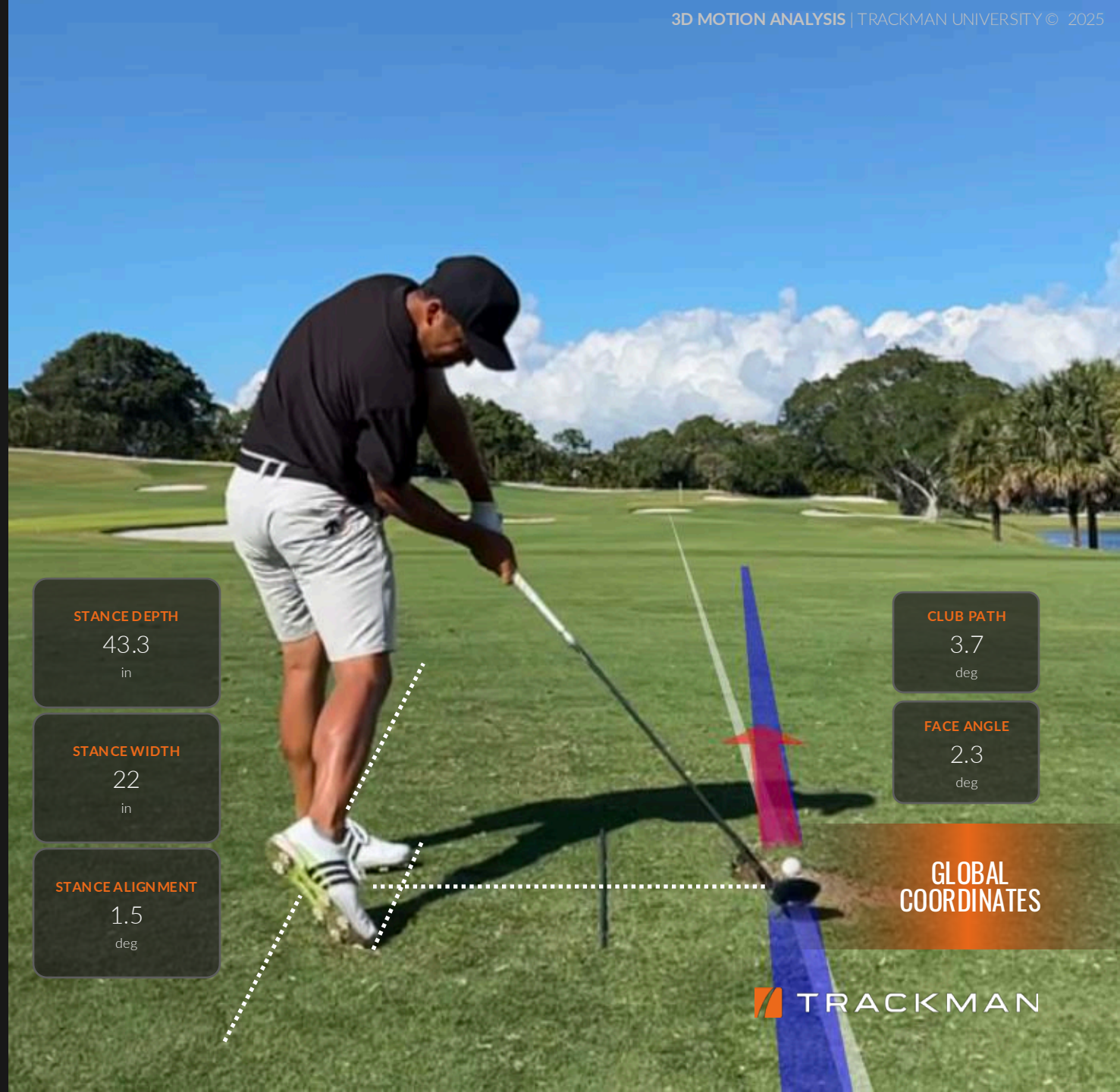
GLOBAL COORDINATE SYSTEM REFERENCES

Fixed to the environment (e.g., room or range), measures motion relative to a universal reference frame (target line).

- ✓ Overall movement in 3D space
- ✓ Fixed in space
- ✓ Common origins
- ✓ Used to track “whole-body movement”
- ✓ Used for ball flight and club data

Examples

- The Stance Alignment is 1.5° closed
- The Stance Depth is 43.3 inch
- The Club Path is +3.7 ° at impact



Definitions & Coordinate Systems

LOCAL COORDINATE SYSTEM REFERENCES

Fixed to the body segment itself (e.g., pelvis, shoulders), measures motion relative to the orientation of that body part.

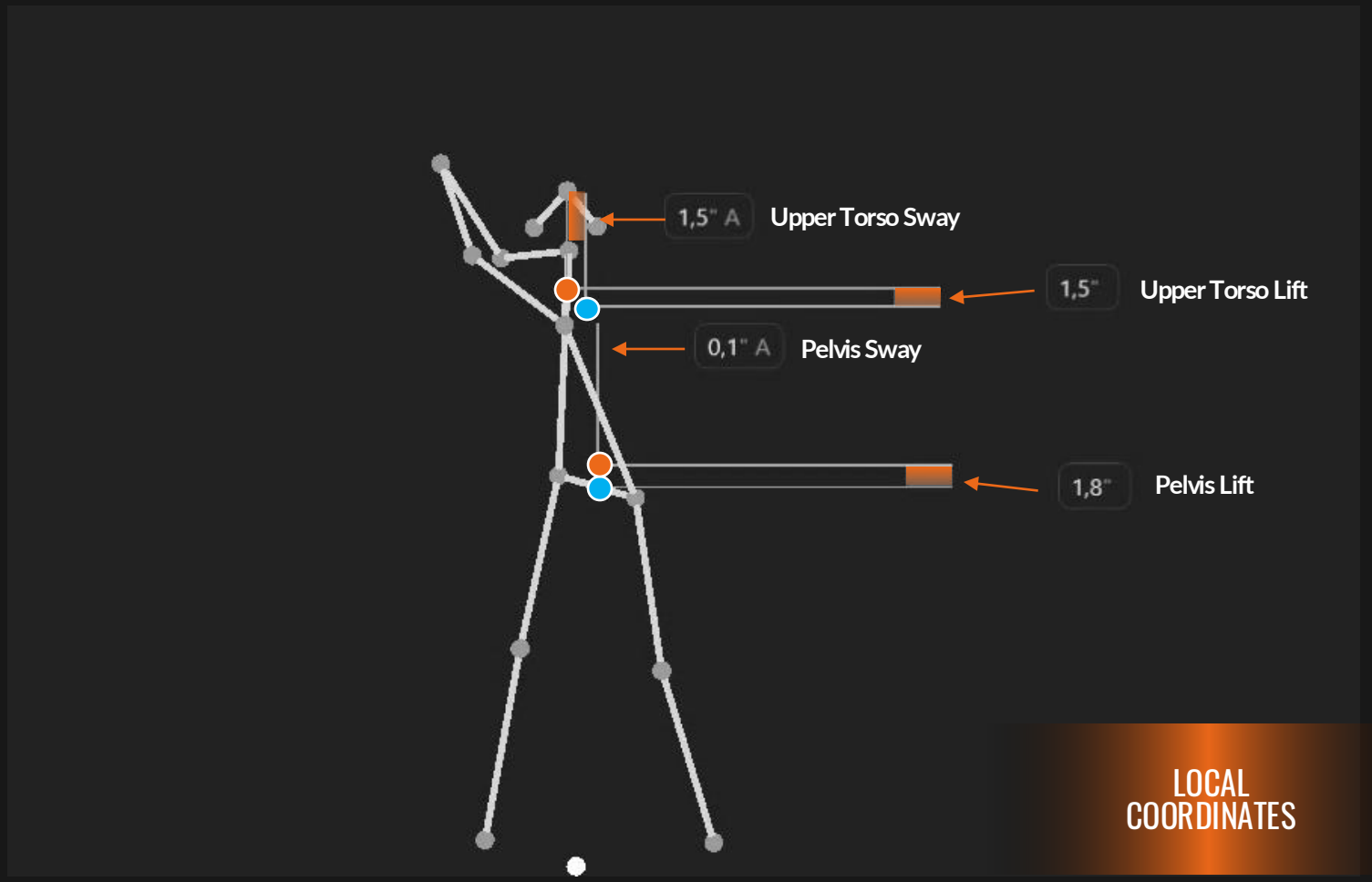
- ✓ Moves with the body segment
- ✓ Defines movement relative to the segment(s)
- ✓ Used to track joint and segment relations

Examples

From P1 to P4

→ The Upper Torso had 1.5” of sway

→ The Pelvis had 1.8” lift



Definitions & Coordinate Systems

BODY MOTION COMPARED TO CLUB DATA

Body motion is captured in 3D with 6DOF

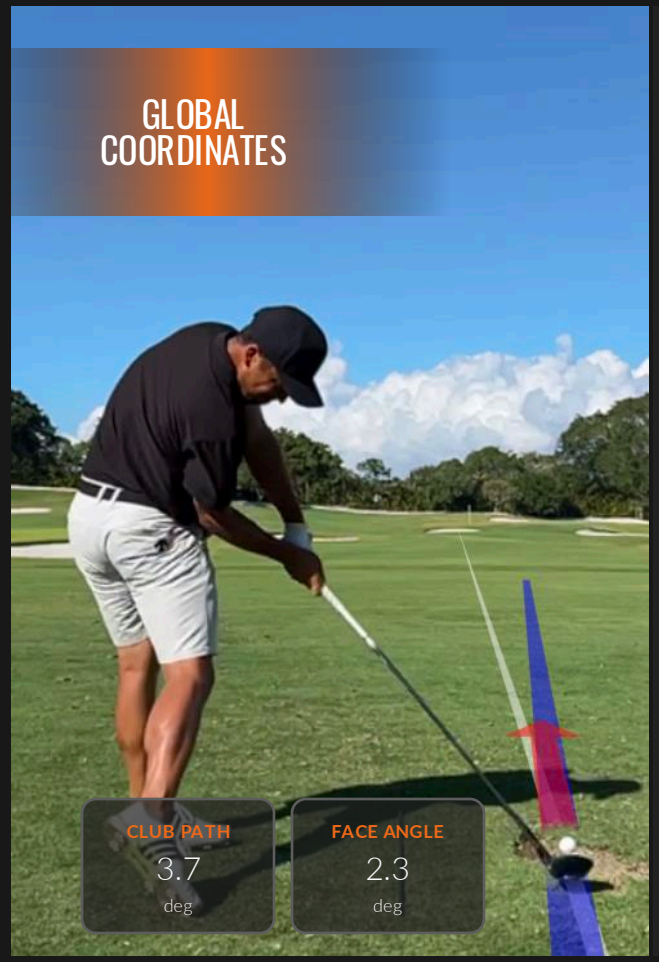
- **Linear translations** (sway, thrust, lift) are expressed to the global frame, but local in the sense that they are reset to zero at P1 (address position)
- **Rotations** (bend, tilt, turn) are measured relative to the target, ground and vertical and expressed in the global frame

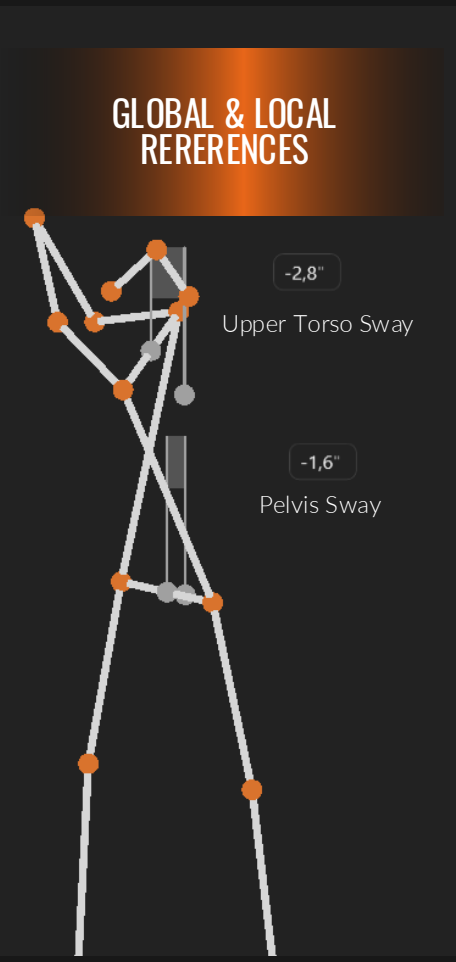
Example: The pelvis moved 1.6" away (sway) from target at P4

Club & Ball Data are captured in 3D and reported in 2D

Trackman measures 3D club data that is expressed in two dimensions at impact, defined relative to a global reference. Focuses on cause-effect of ball flight.

Example: Club Path +3°, Face Angle +2.3° and -2° Attack Angle.





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Definitions & Coordinate Systems

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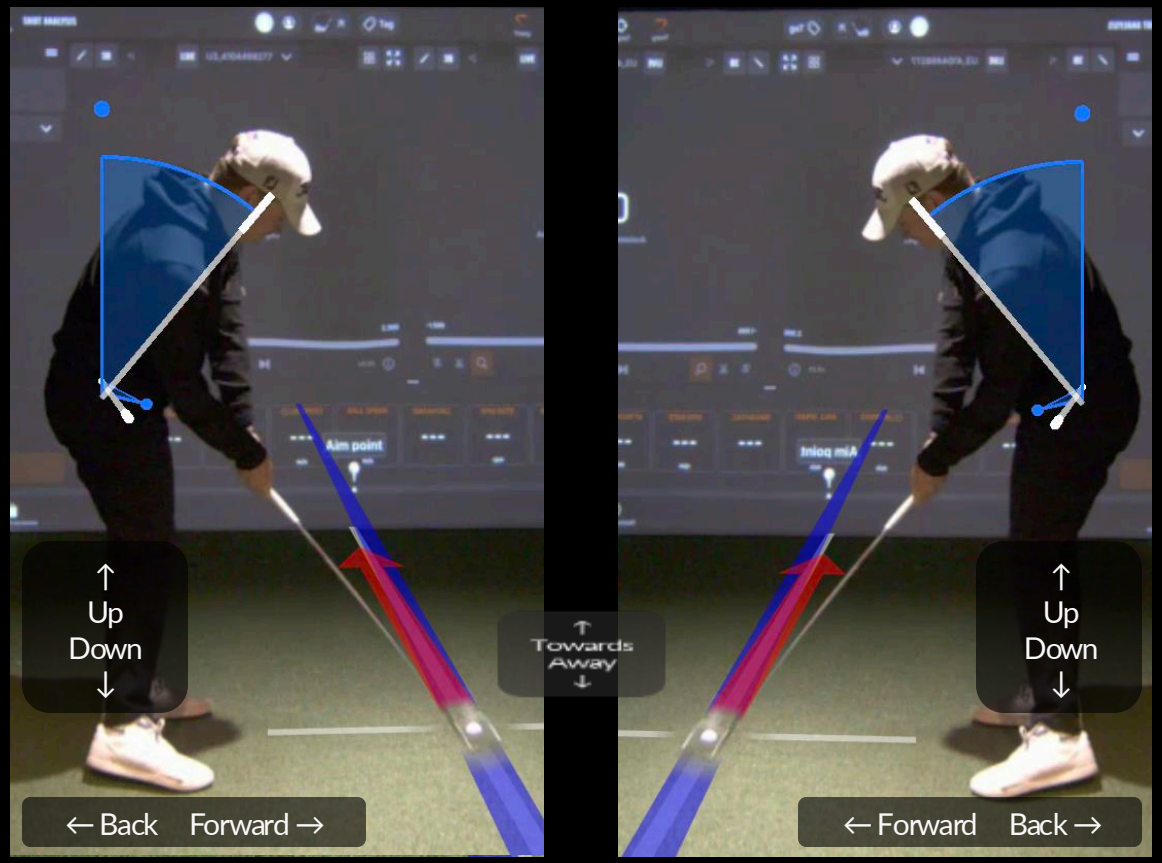
HOW REFERENCES ARE VIEWED FROM A DEXTERITY PERSPECTIVE



Note that club data is always using Global coordinates fixed to target line, meaning that an "inside-out" Club Path for RH is positive and negative for LH.

Rotations	Common Term	Abbreviation	Relative To	Zero Reference
Head Turn	Away/Towards	A and T	Target	Target line
Upper Torso Turn	Away/Towards	A and T	Target	Target line
Pelvis Turn	Away/Towards	A and T	Target	Target line
Head Tilt	Away/Towards	A and T	Target	Vertical
Upper Torso Tilt	Away/Towards	A and T	Target	Vertical
Pelvis Tilt	Away/Towards	A and T	Target	Vertical
Head Bend	Forward/backward	F and B	Ball	Horizon
Upper Torso Bend	Forward/backward	F and B	Ball	Horizon
Pelvis Bend	Forward/backward	F and B	Ball	Horizon
Posture bend	Upright/bent over	-	Vertical line/ball	Vertical
Posture tilt	Right/left lean	-	Vertical line/target	Vertical
Translations				
Head Sway	Away/Towards	A and T	Target	P1
Upper Torso Sway	Away/Towards	A and T	Target	P1
Pelvis Sway	Away/Towards	A and T	Target	P1
Head Thrust	Forward/backward	F and B	Ball	P1
Upper Torso Thrust	Forward/backward	F and B	Ball	P1
Pelvis Thrust	Forward/backward	F and B	Ball	P1
Head Lift	Down/Up	D and U	Ball	P1
Upper Torso Lift	Down/Up	D and U	Ball	P1
Pelvis Lift	Down/Up	D and U	Ball	P1
Setup & Alignment				
Upper Torso Alignment	Open/Closed	O and C	Target line	Target line
Pelvis Alignment	Open/Closed	O and C	Target line	Target line
Stance Alignment	Open/Closed	O and C	Target line	Target line
Stance Depth	Close to/far from	-	Ball	Ball
Stance Width	Narrow/wide	-	Ankles	Ankles together
Ball Position	Away/Towards	A and T	Perpendicular, midpoint	Midpoint between ankles

Definitions & Coordinate Systems

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KEY FRAMES USING P POSITIONS

Toggle quickly between P1-P10 positions in TPS

These positions are automatically mapped using AI tracking, so you can quickly toggle between the P-positions on the keyboard

The lead arm is the straight line between the shoulder and wrist, even if bent.

This consistent reference tracks motion regardless of elbow flexion.

Definitions & Coordinate Systems

CONNECT
BODY & CLUB

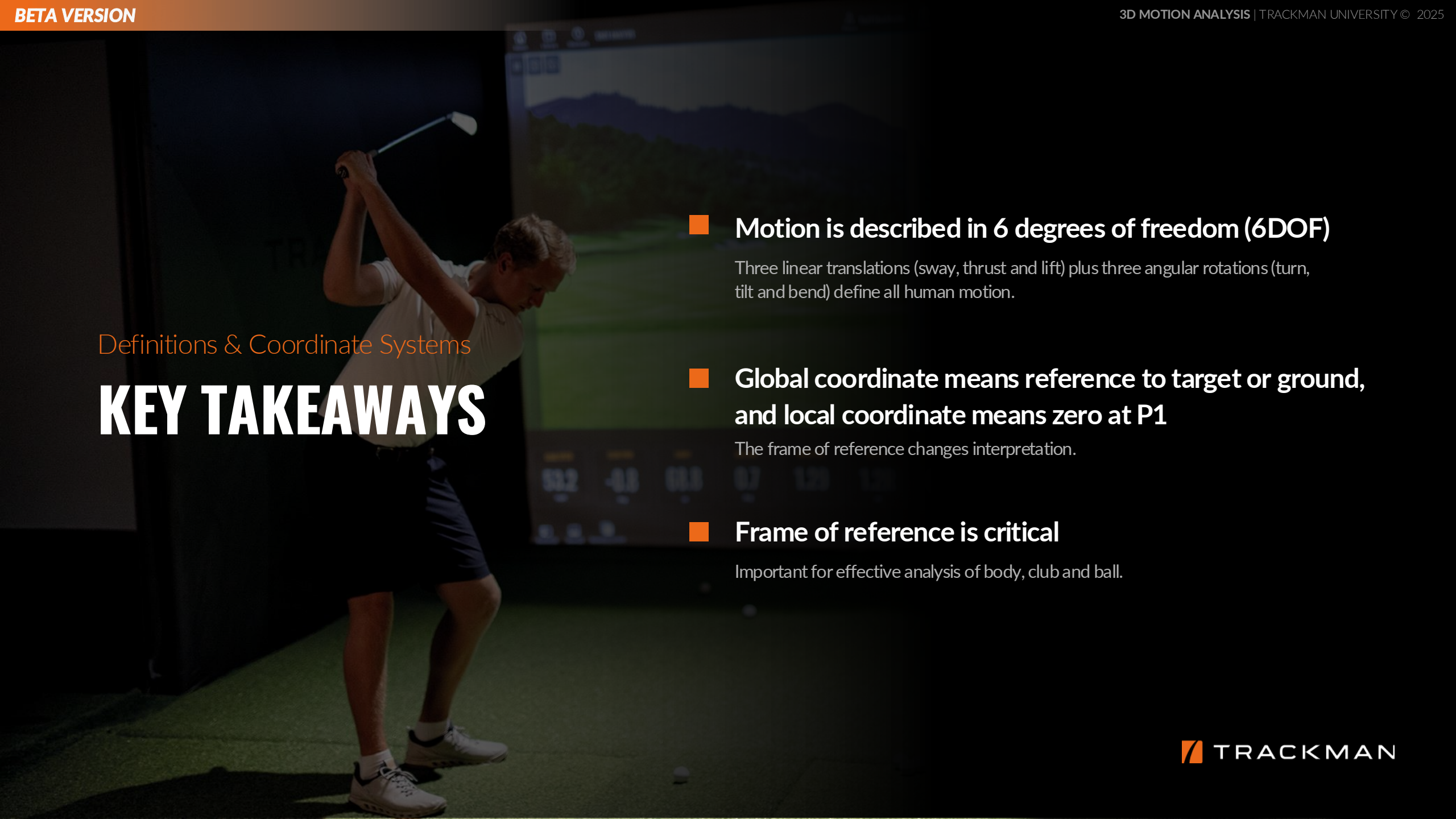
Combining body and club leads to better diagnosis, better coaching and better outcomes.

Ball data shows **what happened.**
Club data shows **how it happened.**
Body data shows **why it happened.**

With Trackman 3D Motion Analysis, you can measure

- ✓ Setup with alignment and posture
- ✓ Rotational and translational movement in the pelvis and upper torso

→ and connect these directly to club and ball data.



Definitions & Coordinate Systems

KEY TAKEAWAYS

- **Motion is described in 6 degrees of freedom (6DOF)**

  Three linear translations (sway, thrust and lift) plus three angular rotations (turn, tilt and bend) define all human motion.

- **Global coordinate means reference to target or ground, and local coordinate means zero at P1**

  The frame of reference changes interpretation.

- **Frame of reference is critical**

  Important for effective analysis of body, club and ball.

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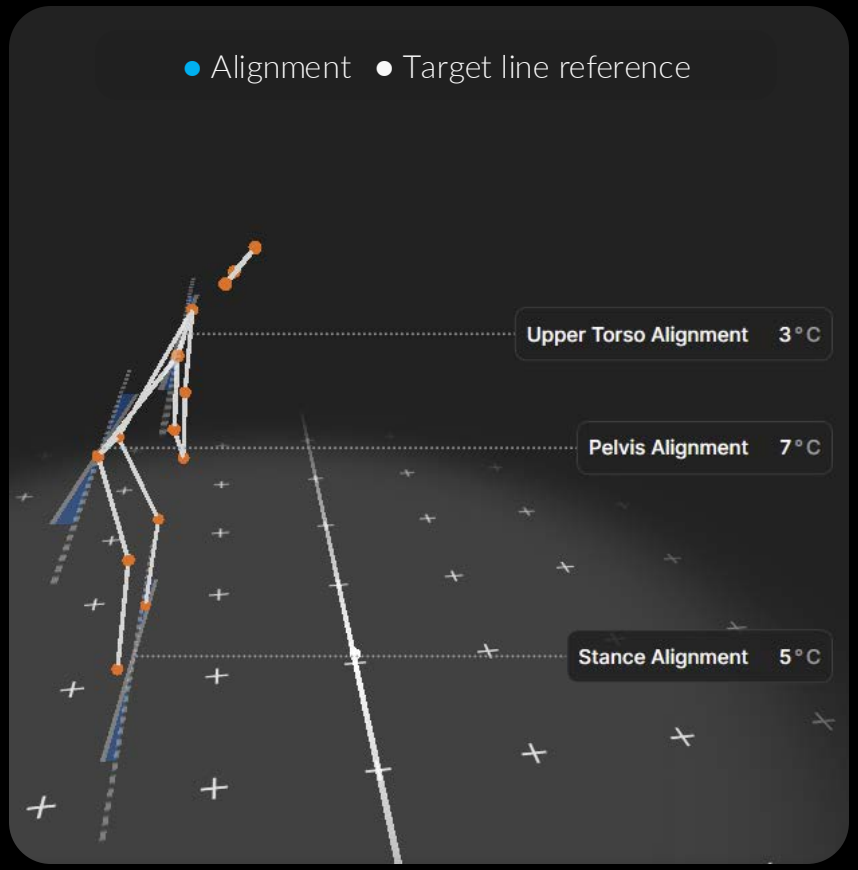
3D MOTION ANALYSIS METRICS

Chapter 5: Making Use of The Data

Trackman 3D Motion Analysis Metrics

ALIGNEMENT IN THE GOLF SWING



Alignment at setup sets the body's orientation to the target. It provides the reference for motion and club delivery — consistent alignment supports repeatability, while poor alignment can lead to compensations and inaccuracy.

Upper Torso
The direction of the shoulder line relative to the target line. Strongly influences club path and swing plane. The directional alignment of the upper torso relative to the target at setup can bias the swing direction.

Pelvis
Hip line sets the base for rotation and weight shift. Neutral pelvis alignment promotes efficient kinematics.

Stance (Ankles)
The line between the ankles indicates stance direction. Works with stance width and depth to set balance and stability. Misaligned stance alters pressure shift and motion patterns.

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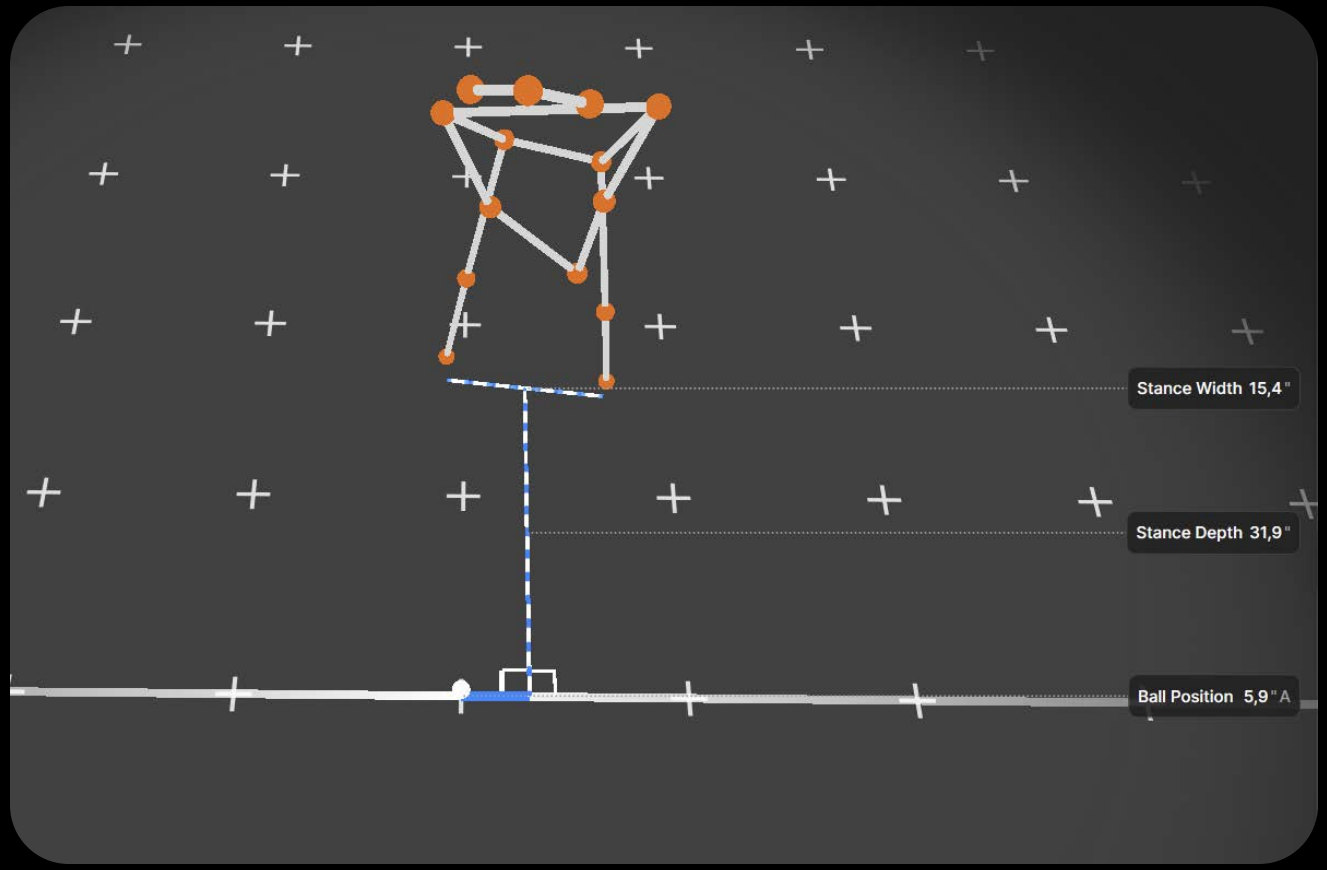
Trackman 3D Motion Analysis Metrics

STANCE & BALL POSITION



Stance and ball position form the foundation of balance, range of motion, and strike consistency. They influence low point control and directly shape club delivery and the resulting ball flight.

Stance Width
Stance width balances stability and mobility. A wider stance adds stability and potentially greater moment arm but reduces motion; a narrower stance increases mobility but limits stability.

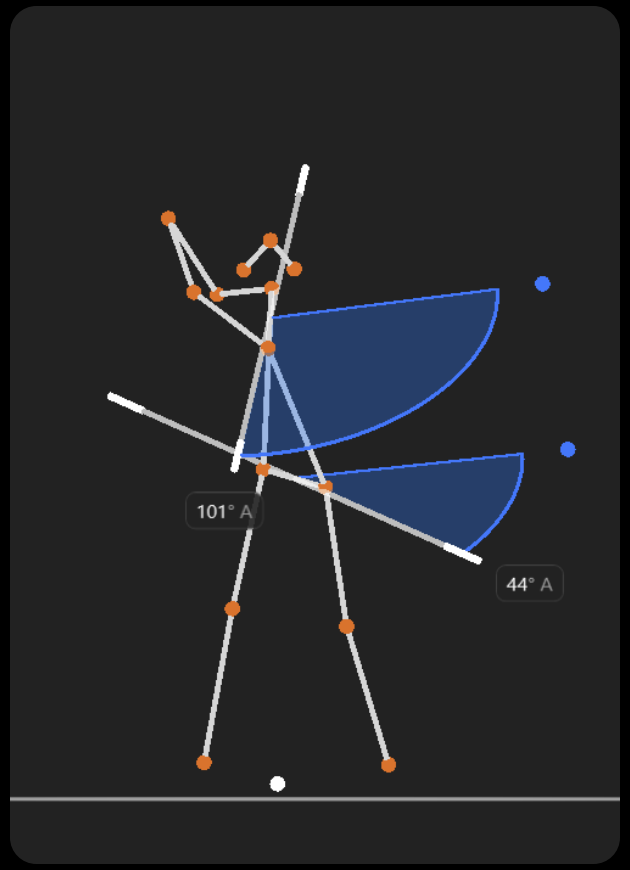
Stance Depth (Distance to ball)
Closer depth can steepen the plane; farther depth can flatten the plane.

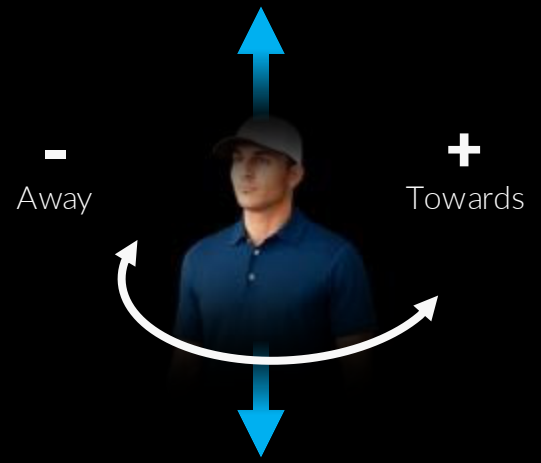
Ball Position
Forward promotes a more positive Attack Angle and back promotes a more negative Attack Angle, unless low point is changed. This will also influence the Club Path based on the Low Point vs Swing Direction combination.

TRACKMAN

Trackman 3D Motion Analysis Metrics

TURN





Turn is the rotation around the up-down axis

The towards and away rotation around the vertical axis.

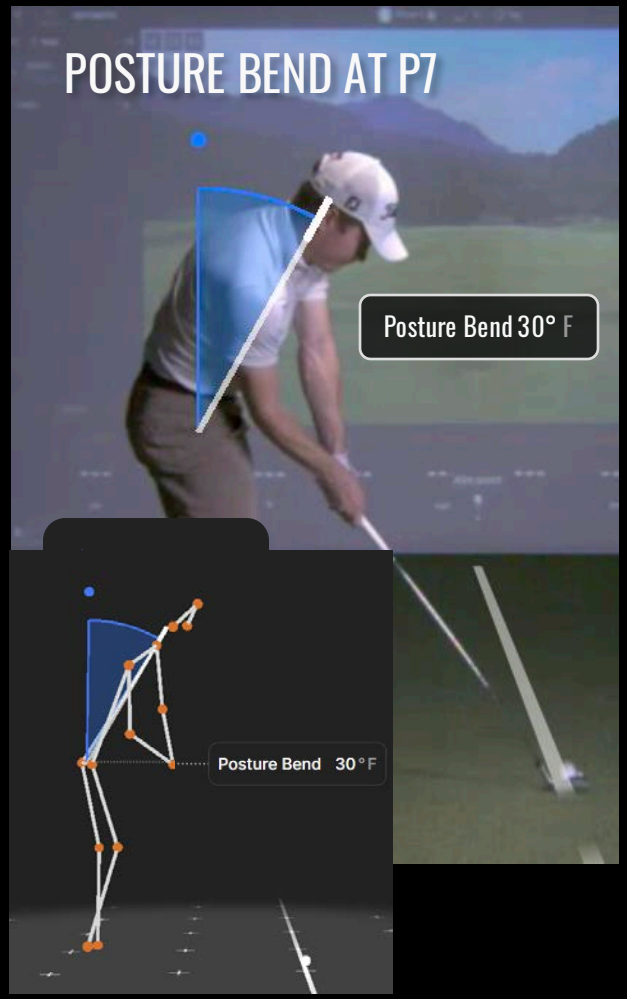
Negative values indicate a turn away from the target (also referred to as closed, towards the trail side, away from the target).

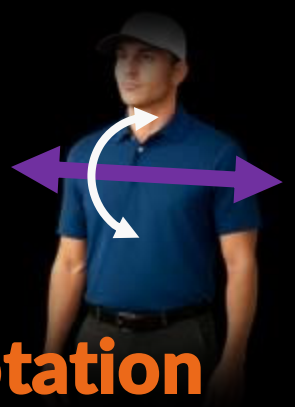
Available for
- Head
- Upper Torso
- Pelvis

TRACKMAN

Trackman 3D Motion Analysis Metrics

BEND





Bend is the rotation around the side-to-side axis

The forward and backwards bends around the horizontal side-to-side axis.

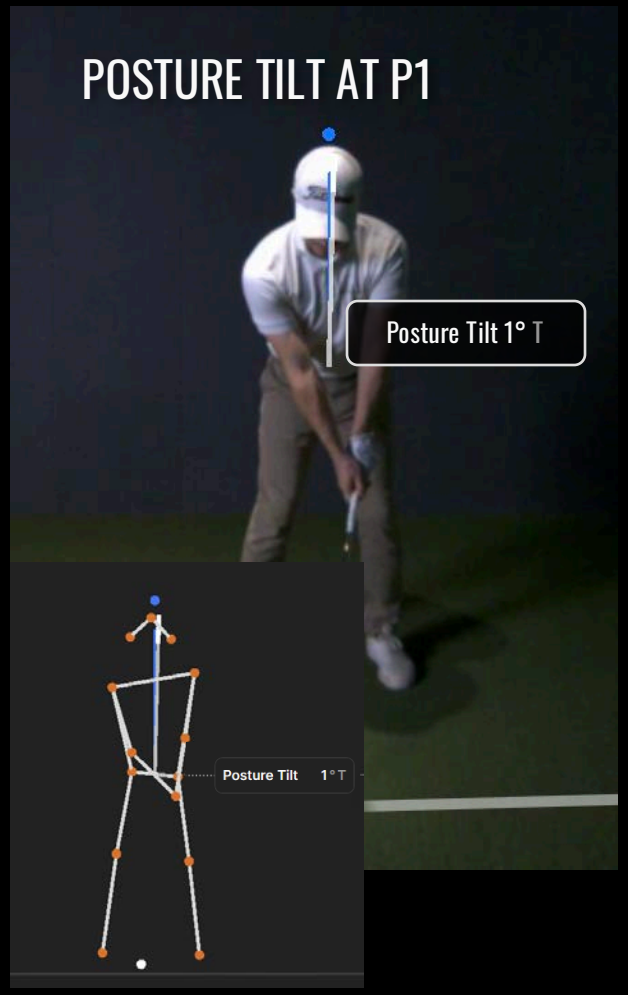
Positive values indicate a forward bend (F) towards the ground.

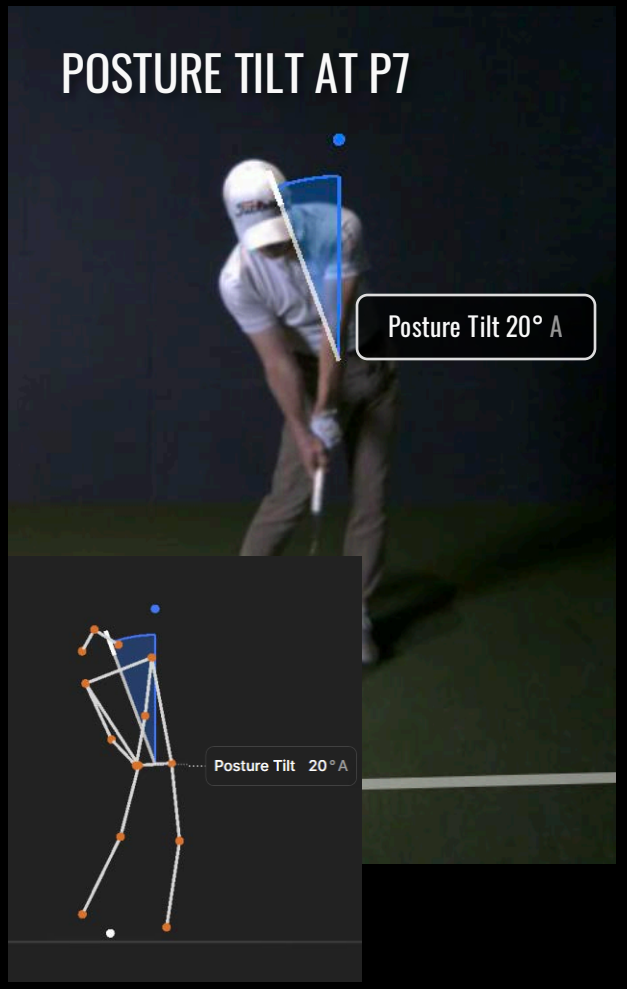
Available for
- Head
- Upper Torso
- Pelvis
- Posture (spine)

TRACKMAN

Trackman 3D Motion Analysis Metrics

TILT





Tilt is the rotation around the front-back axis

The inclination of the joint line around the horizontal front-back axis.

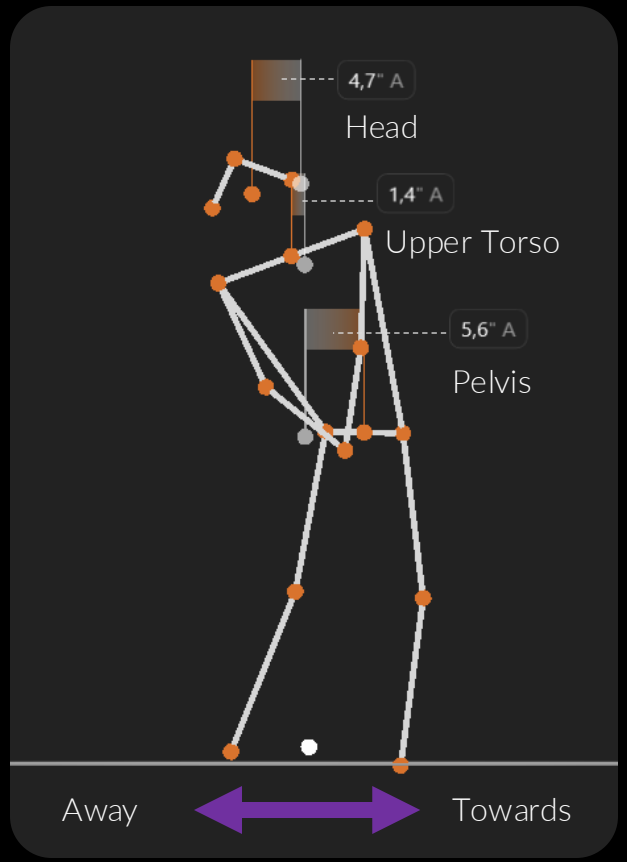
Positive values indicate the trail side is lower than the lead side.

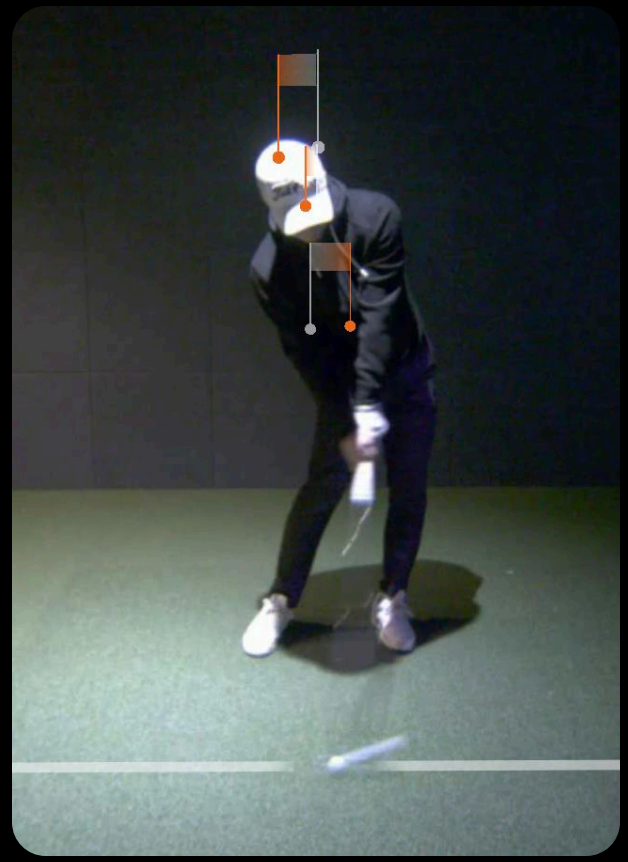
Available for
- Head
- Upper Torso
- Pelvis
- Posture (spine)

TRACKMAN

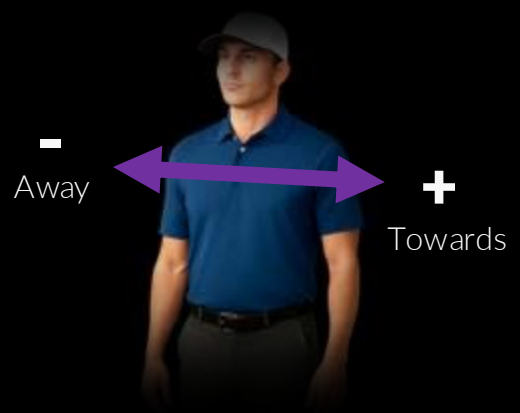
Trackman 3D Motion Analysis Metrics

SWAY





● Setup (P1) ● Current frame (P7)



Sway is the side-to-side translation

Lateral movement toward or away from the target along the horizontal side-to-side axis.

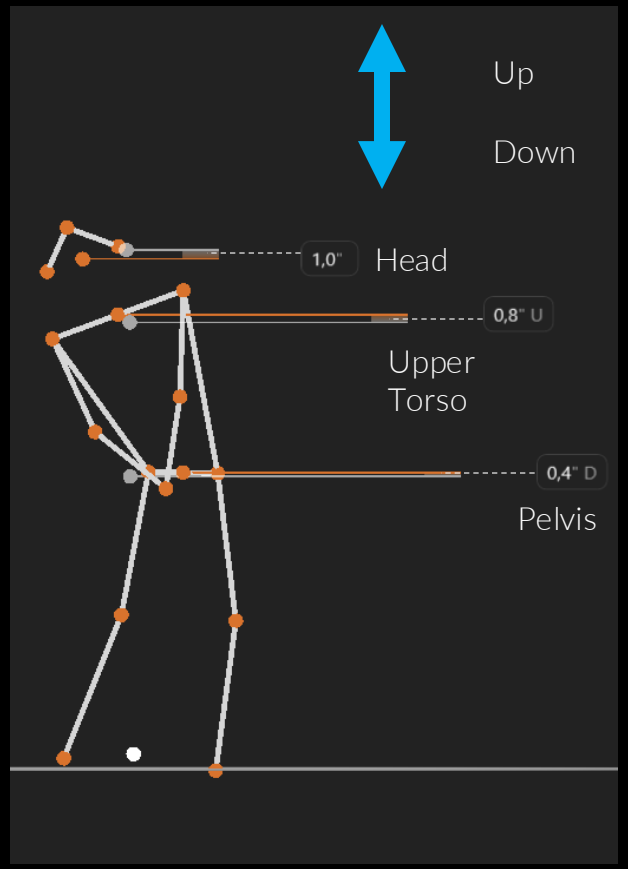
Positive values indicate motion towards the target.

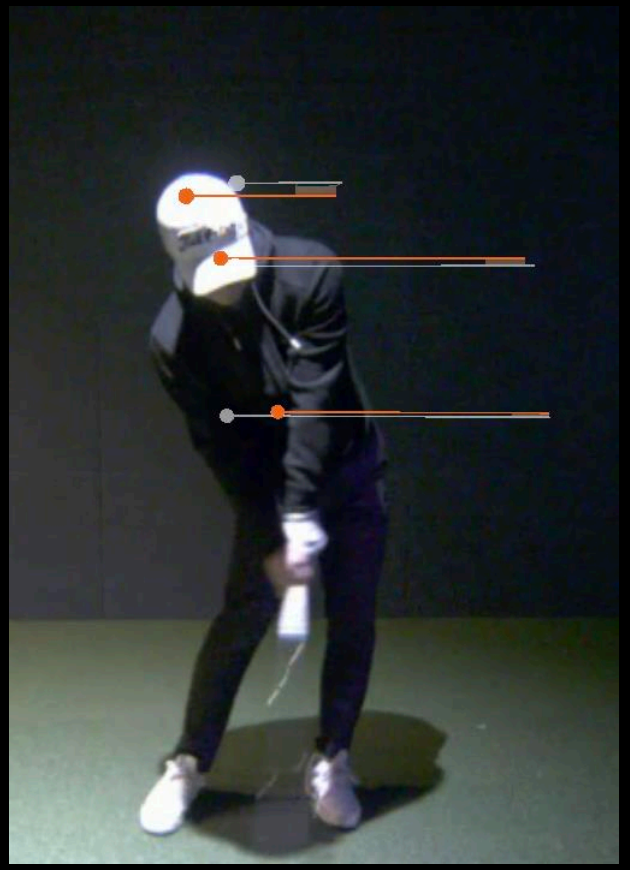
Available for
- Head
- Upper Torso
- Pelvis

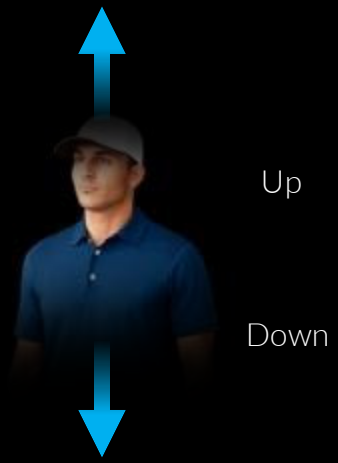
TRACKMAN

Trackman 3D Motion Analysis Metrics

LIFT







Lift is the up-down translation

Lateral movement up or down relative to the ground, along the vertical axis.

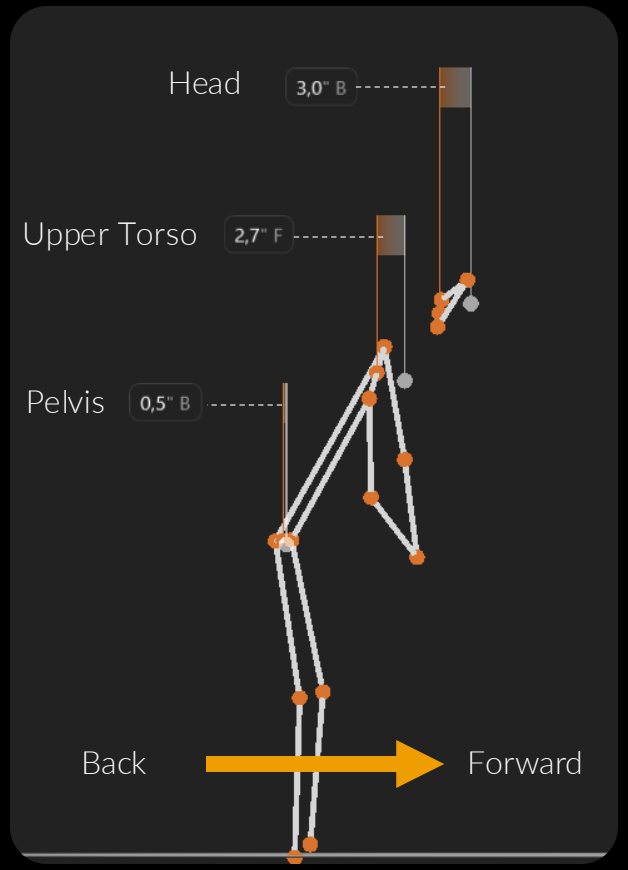
Positive values indicate motion up away from the ground.

Available for
- Head
- Upper Torso
- Pelvis

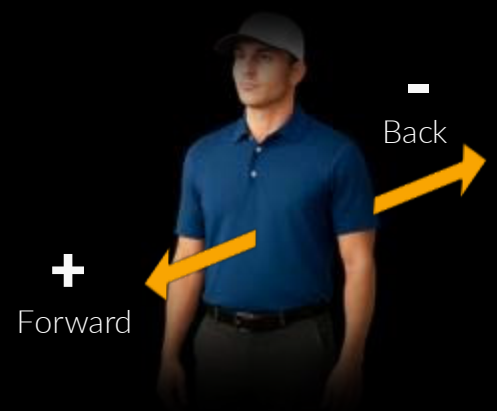
● Setup (P1) ● Current frame (P7)

Trackman 3D Motion Analysis Metrics

THRUST



● Setup (P1) ● Current frame (P7)



Thrust is the forward-back translation

Lateral movement forward or back relative to the target line (ball), along the Forward-Back axis.

Positive values indicate motion forward, towards the target line (ball).

Available for
- Head
- Upper Torso
- Pelvis

TRACKMAN

Trackman 3D Motion Analysis Metrics

INTERPRETATION OF NUMBERS

It's not about perfect numbers and comparing to tour players, but about what the numbers mean for the player in front of you.

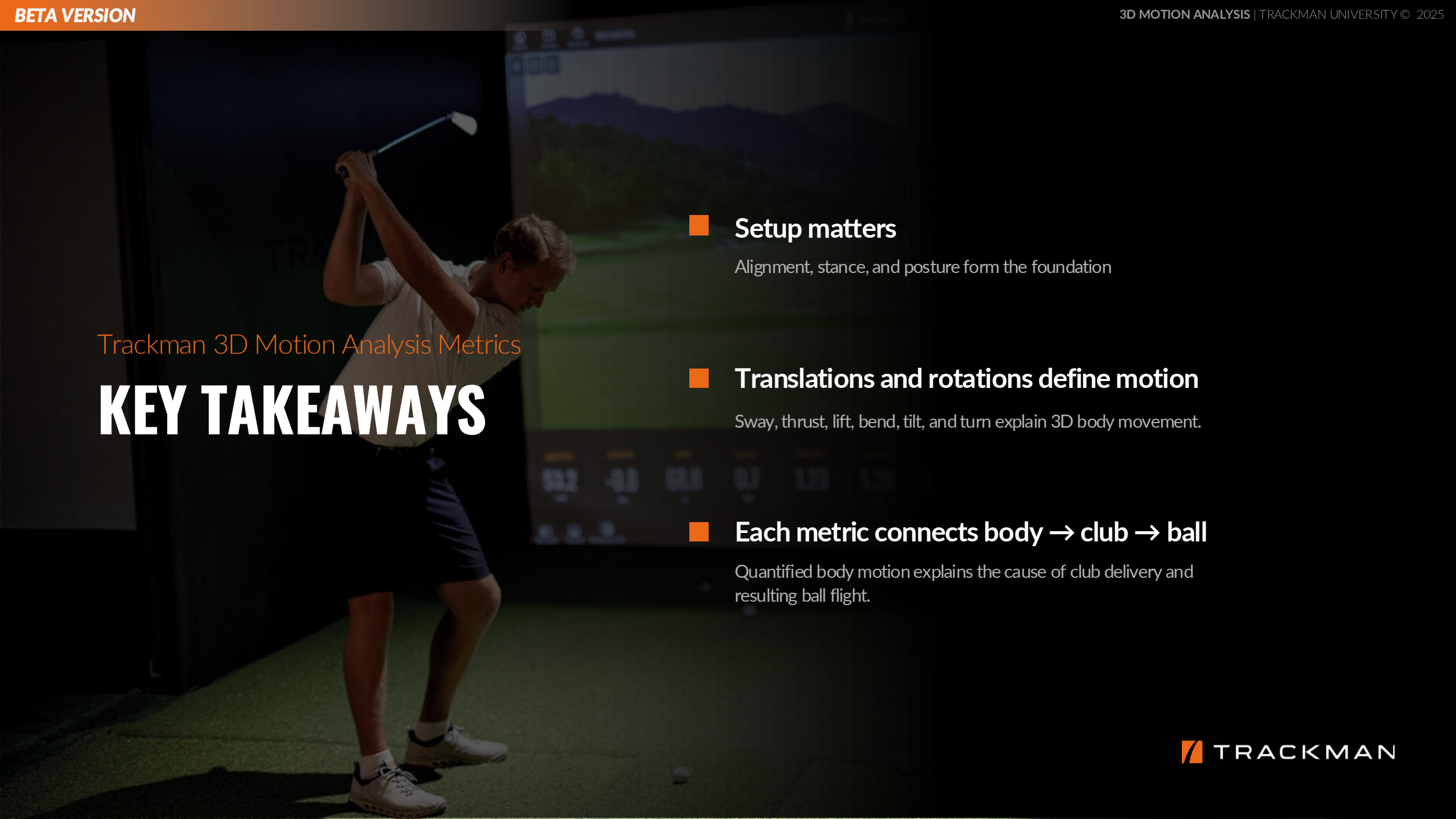
When analyzing data, think in two parts:

1. **Competency** → *Does the player have the coordination and control to make a movement?*
2. **Capacity** → *How much of that movement is available to them?*

The goal is to connect these factors to how the body moves, how the club is delivered, and the ball flight it produces.

"Coaches must connect motion data not only to outcomes, but also to what the player is physically able to do."

TRACKMAN



Trackman 3D Motion Analysis Metrics

KEY TAKEAWAYS

Setup matters

Alignment, stance, and posture form the foundation

Translations and rotations define motion

Sway, thrust, lift, bend, tilt, and turn explain 3D body movement.

Each metric connects body → club → ball

Quantified body motion explains the cause of club delivery and resulting ball flight.

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TRACKMAN UNIVERSITY

BIOMECHANICS

SETUP & CAMERA CALIBRATION

A Better Viewing Experience

Setup & Camera Calibration

TRACKMAN

CAMERA POSITIONS FOR BEST VIEWING PERSPECTIVE

The camera position matters for your video experience, but not for 3D Motion Analysis accuracy

For Video
Changing camera angles alters how the swing looks. A slightly different position can make body motion or club positions appear different, even if the swing is the same.

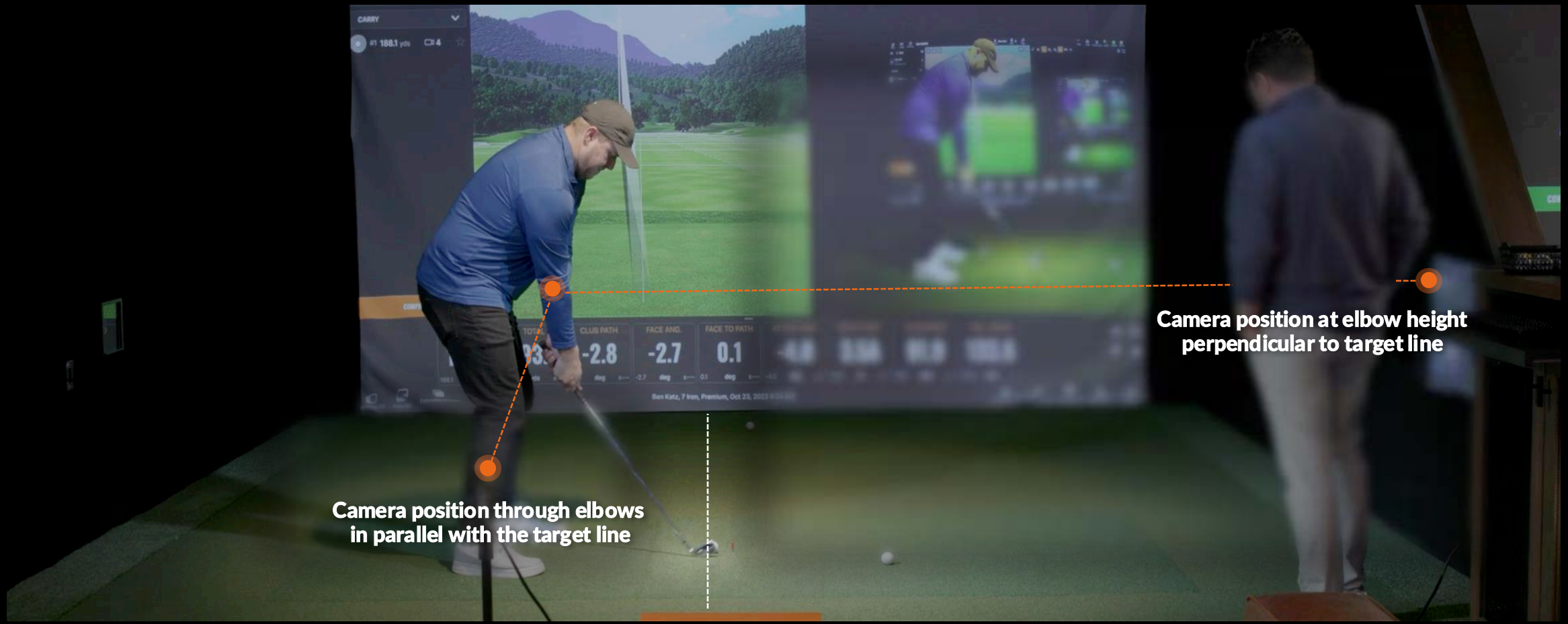
For 3D Motion Analysis
Camera calibration eliminates this problem. The 3D system measures actual motion in space, so the data is unaffected by camera perspective.

Camera angles changes the perspective, but not the data.

Setup & Camera Calibration

TRACKMAN

CAMERA POSITIONS FOR BEST VIEWING PERSPECTIVE



Setup & Camera Calibration

CAMERA REQUIREMENTS FOR 3D MOTION ANALYSIS

2 calibrated cameras are needed for 3D metrics to be tracked.

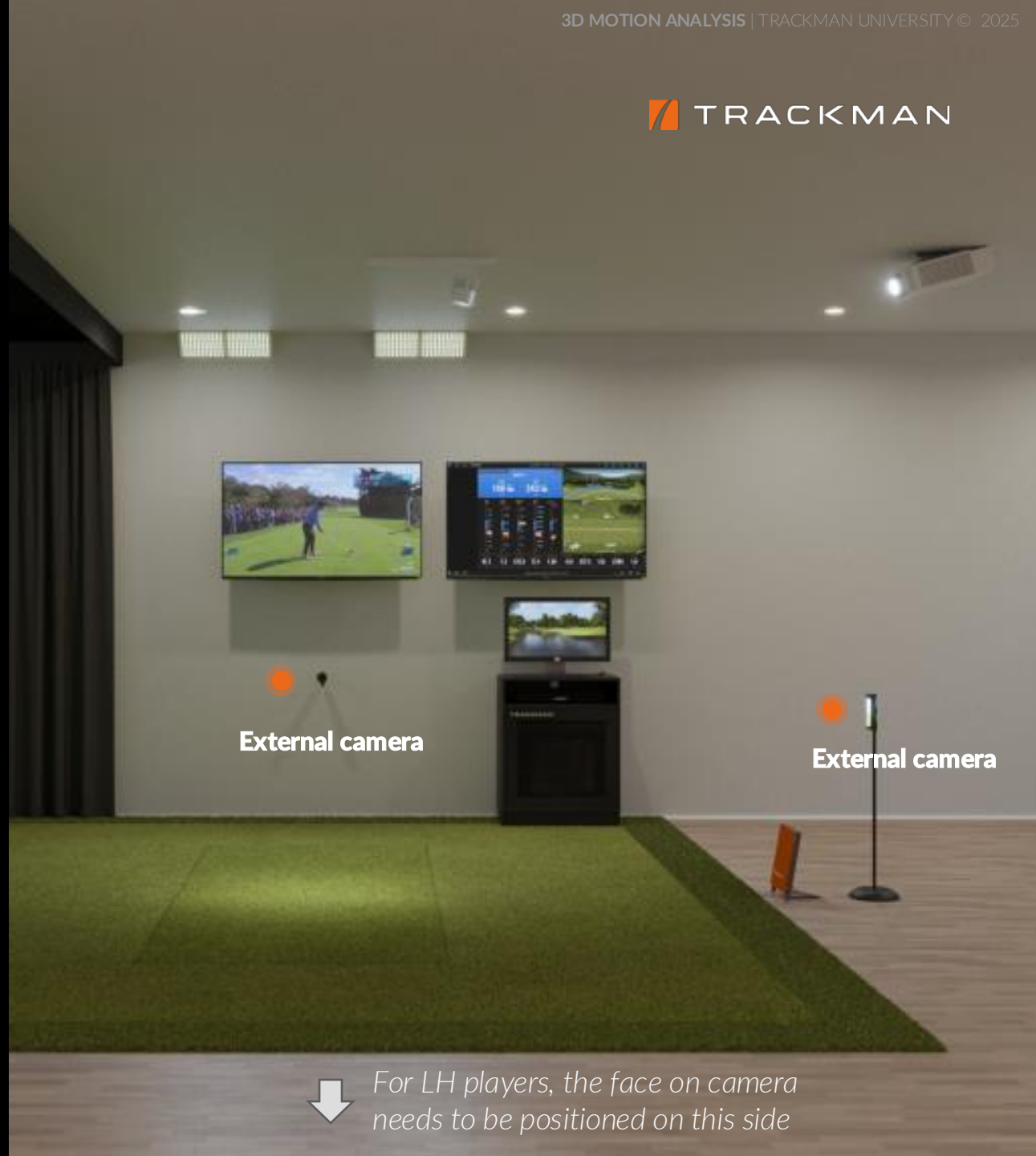
- ✓ IDS and iOS are recommended
- ✓ Econ is supported

Requirements

- The cameras need to be fixed and calibrated in TPS
- Lights are important when filming indoors
- IDS cameras have advanced settings with options to set custom profiles for shutter speed, resolution, fps and more

Visit support.trackmangolf.com to learn more

Search for "USB Swing Camera Profile in TPS



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FOR A BETTER GAME