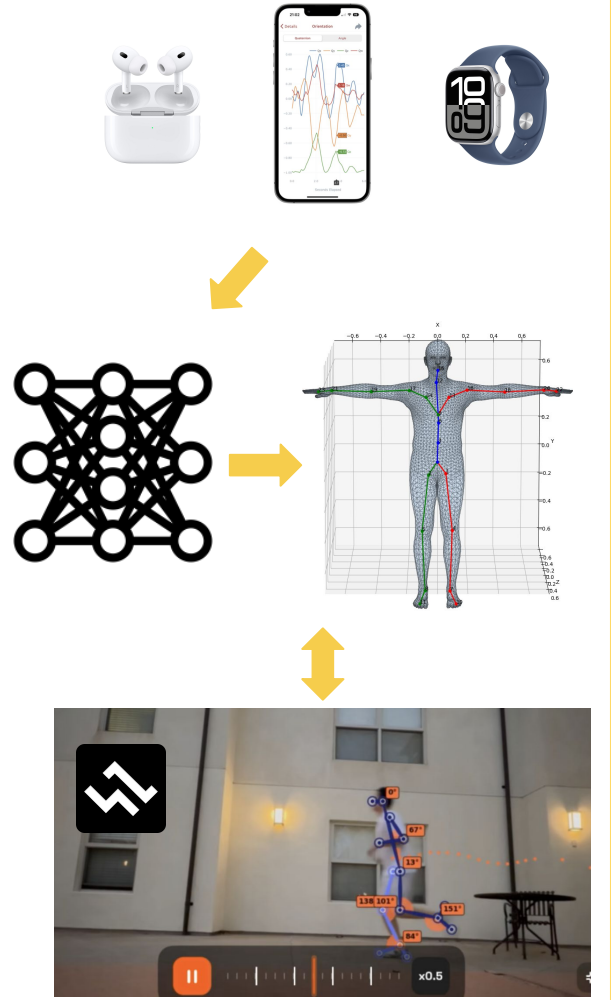
SymStride

Michael, Ido, Yibo

Motivations and Objectives

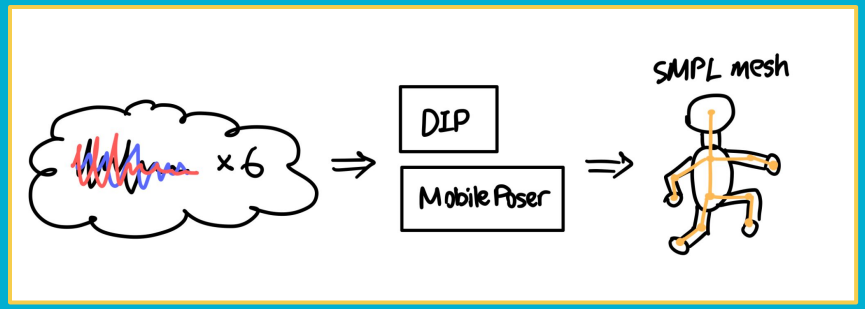
- **Motivation**
  - Video based running analysis (like Ochy) needs cameras, lighting, and privacy trade-offs.
  - IMUs are low-cost, portable, and enable motion tracking
- **Objectives**
  - Use pre-existing IMU data + ML models to reconstruct human motion
  - Derive key kinematic metrics from pose (e.g. hip, knee, ankle, elbow angles)
  - Recreate key results from Ochy **without** video capture
- **Impact**
  - **Coach level analysis of running form** for both novice runner and for running enthusiasts **without the need for a flow your day-to-day running**



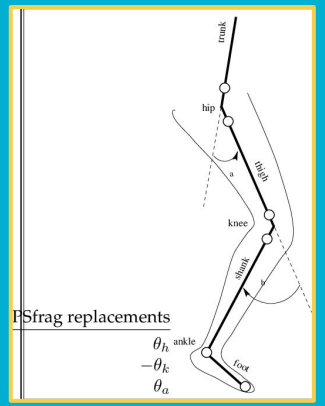
Technical Approach and Novelty

- **Current Approaches:**
  - Optical motion capture:
    - Very accurate but extremely expensive, also requires controlled indoor lab environments
  - Smartphone apps (e.g, Ochy):
    - Uses computer vision from video to estimate 2D or pseudo-3D poses
    - Limited by camera angle, lighting, occlusion, and **need to set up phone as separate from run**
- **Our Approach:**
  - Use IMU configurations placed on predetermined body segments (pelvis, legs, arms, head)
  - Feed IMU data to ML model to reconstruct full 3D pose
  - From reconstructed pose, compute joint angles (hip, knee, ankle, elbow)
  - Use pose to create running metrics outline by current competitors (i.e. Ochy)
- **Novelty:**
  - IMU-only workflow, completely removes the need for cameras or optical markers

Methods



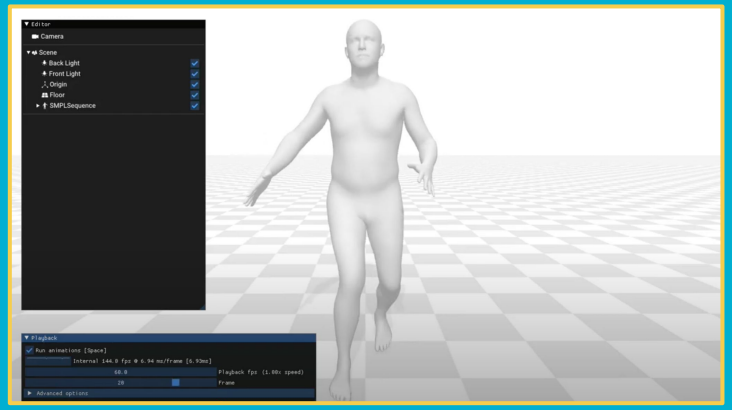
- **Algorithm:**
  - Collect data offline asynchronously
  - **Run the IMU data through pre-existing, fine-tuned ML models to extract the 3D poses**
    - DIP
    - MobilePoser
  - **Relative-rotation computation for angles**
    - Compute relative body part angles to measure difference between body sides and running best practices (e.g. acute angle for leg while running)
- **Data:**
  - AMASS Dataset (Motion Capture Sequences of humans)
    - DIP-IMU
    - TotalCapture
    - CMU
- **Platform:**
  - Python backend (NumPy, PyTorch, aitviewer, local inferencing)
  - Visualization via website
  - SensorLogger (IMU access iPhone, AirPods, Apple watch)



Evaluation and Metrics

- **Goal:** Matching our IMU derived metrics to vision derived metrics in Ochy
- **Approach:**
  - Run the same motion through both systems (Ochy and our IMU pipeline)
  - Compare the resulting hip, knee, ankle, and elbow angles
  - Compare the higher level insights (heel drive, gait cycle, etc.)
- **Metrics** (our derived metrics vs. Ochy's):
  - Mean absolute error per joint angle
  - Standard deviation of error (consistency of our model's estimates across movements)
  - Is the difference significant?
- **Success Criteria:**
  - Small differences and similar angle patterns between IMU calculated joint angles and Ochy's metrics → Similar insights into running form

Current Status and Next Steps



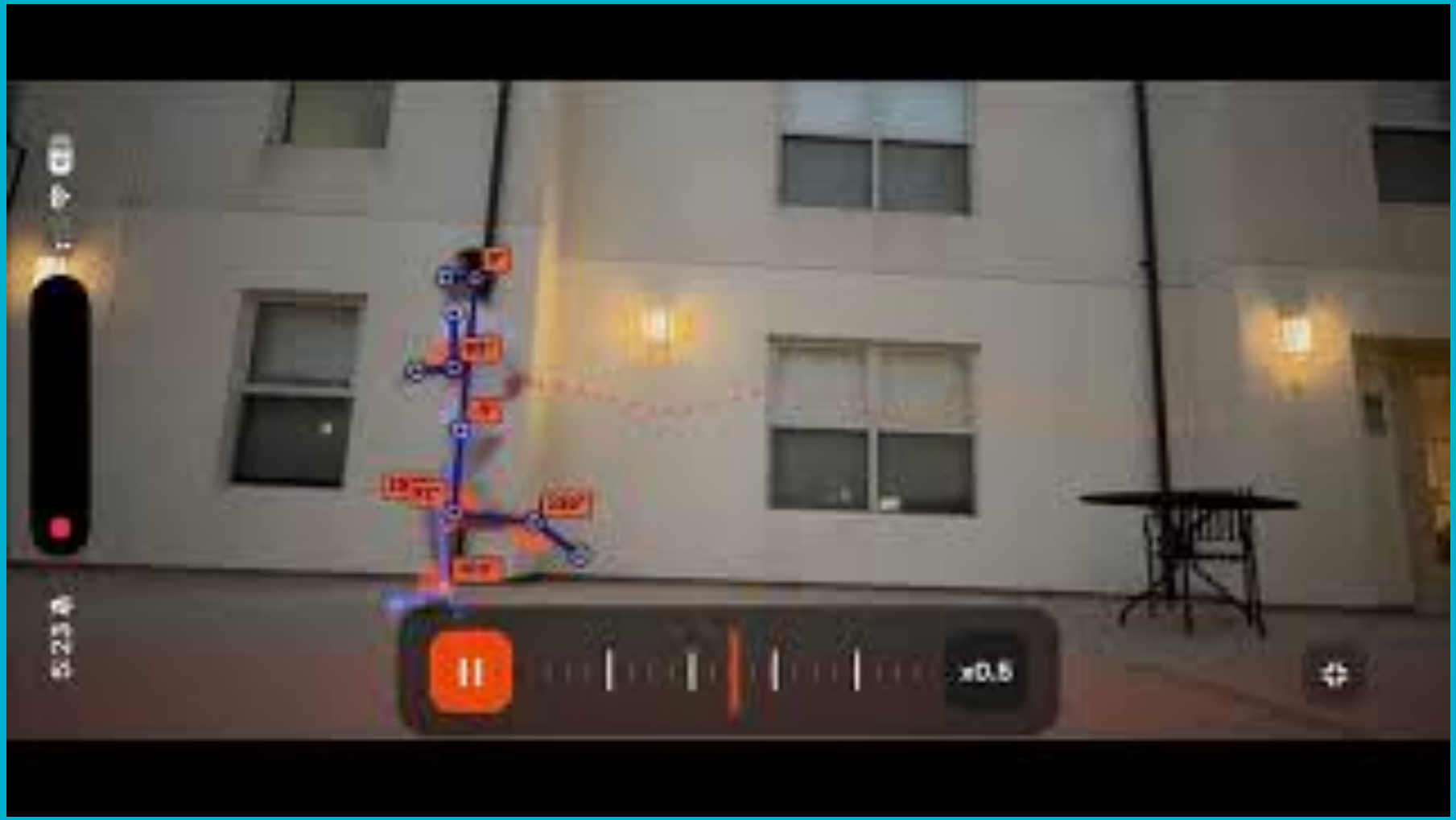
- **Status:**
  - Gotten datasets used for model training
  - Replicated IMU → human mesh pipeline with real IMU data for a few pre-existing models
  - Fine-tune using running data
  - DIP-IMU model produces results with varying accuracy
- **Next Steps:**
  - Explore the calculations for angles and more advanced running form analysis
  - Validate the models with real IMU-Video data
  - Exploring the different combinations of IMU devices we can use
  - Fine tuning model to work with running and reduce jitter

References

V. Xu, C. Gao, H. Hoffmann, and K. Ahuja, “MobilePoser: Real-Time Full-Body Pose Estimation and 3D Human Translation from IMUs in Mobile Consumer Devices,” Human-Computer Interaction, pp. 1–11, Oct. 2024, doi: 10.1145/3654777.3676461.

Y. Huang, M. Kaufmann, E. Aksan, M. J. Black, O. Hilliges, and G. Pons-Moll, “Deep Inertial Poser: Learning to Reconstruct Human Pose from Sparse Inertial Measurements in Real Time,” arXiv.org, Oct. 10, 2018. https://arxiv.org/abs/1810.04703

Thank you!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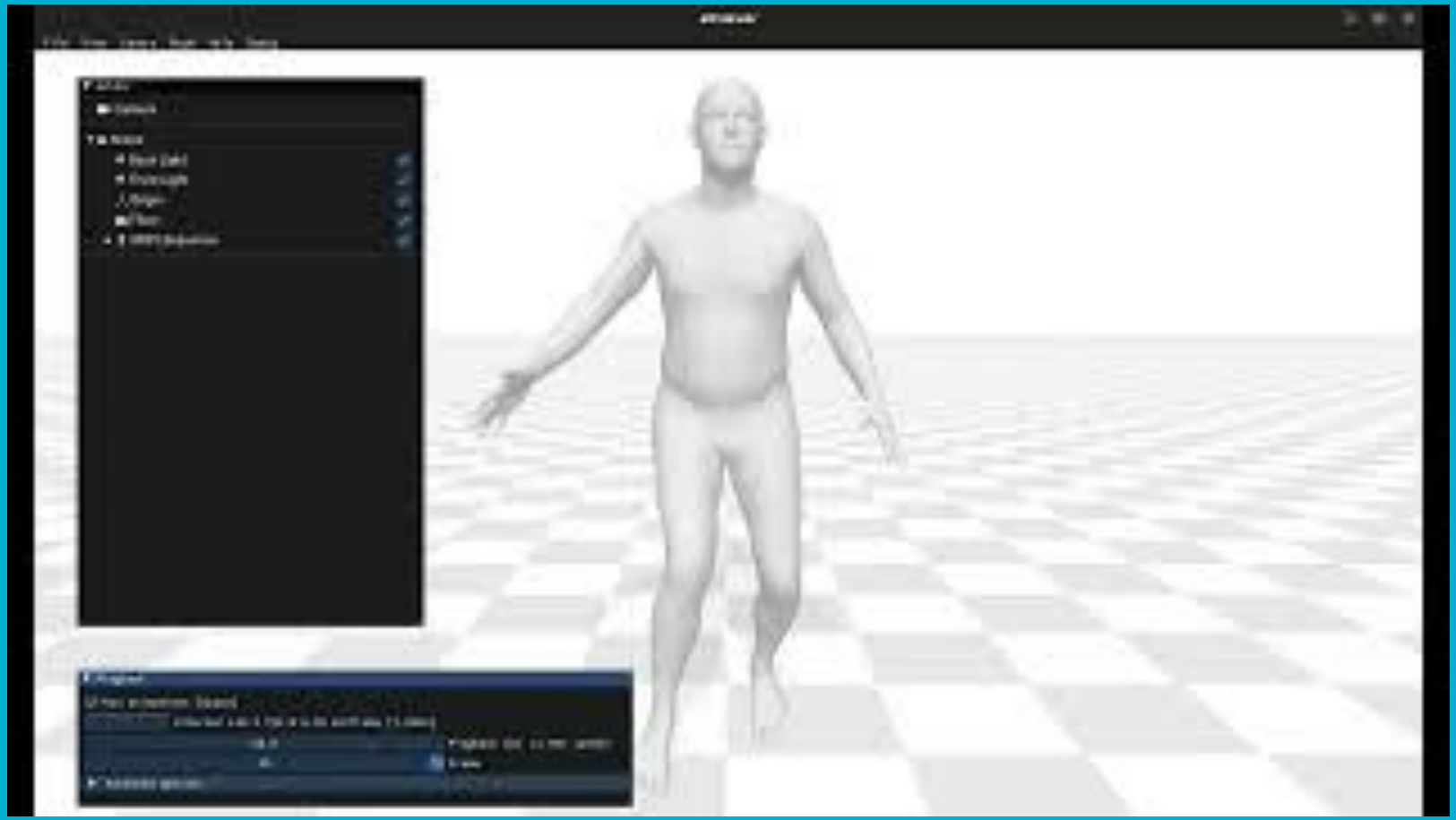
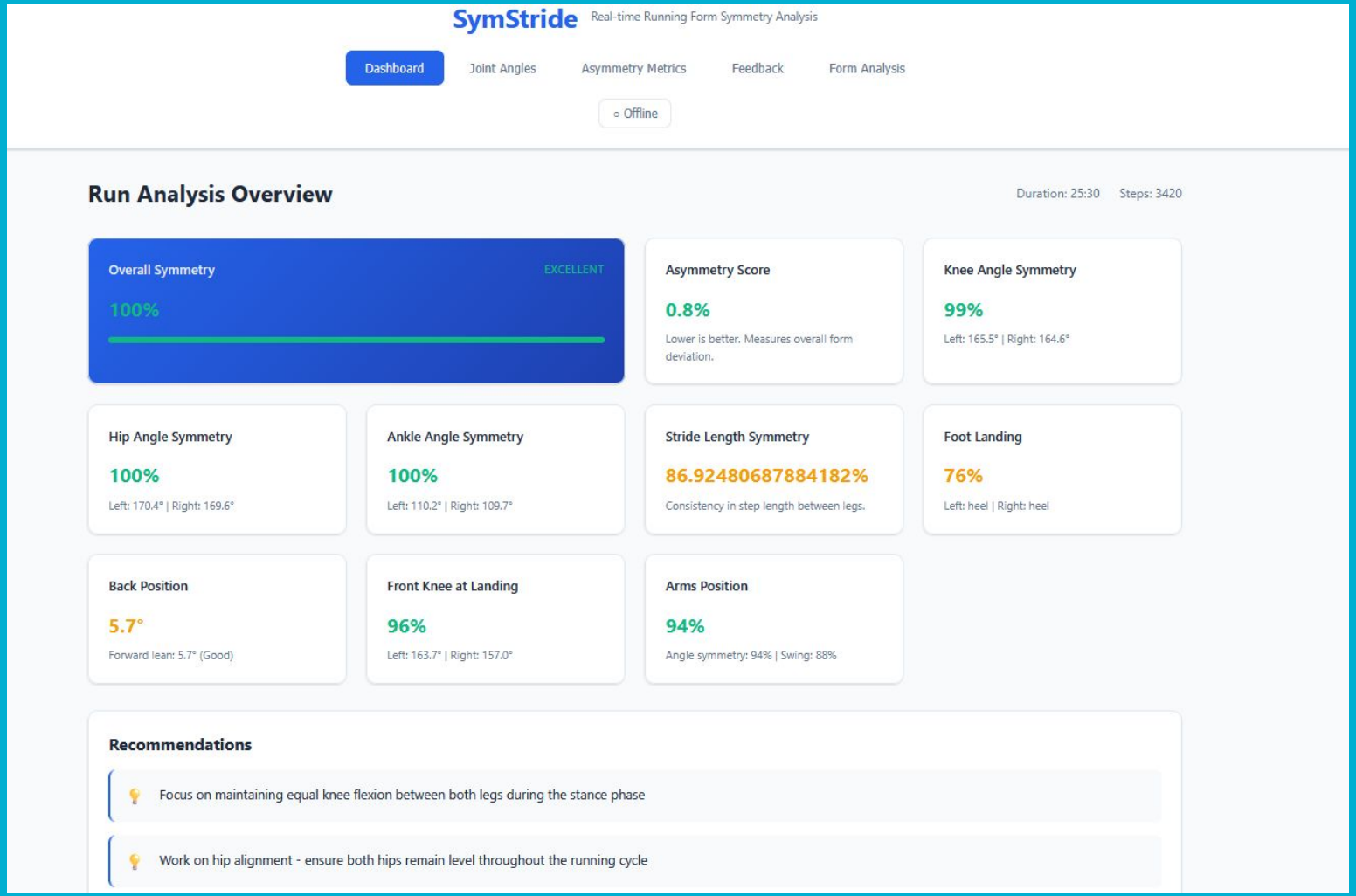



SymStride
Real-time Running Form Symmetry Analysis
Dashboard
Joint Angles
Asymmetry Metrics
Feedback
Form Analysis
○ Offline
Run Analysis Overview
Duration: 25:30
Steps: 3420
Overall Symmetry
EXCELLENT
100%
Asymmetry Score
0.8%
Lower is better. Measures overall form deviation.
Knee Angle Symmetry
99%
Left: 165.5° | Right: 164.6°
Hip Angle Symmetry
100%
Left: 170.4° | Right: 169.6°
Ankle Angle Symmetry
100%
Left: 110.2° | Right: 109.7°
Stride Length Symmetry
86.92480687884182%
Consistency in step length between legs.
Foot Landing
76%
Left: heel | Right: heel
Back Position
5.7°
Forward lean: 5.7° (Good)
Front Knee at Landing
96%
Left: 163.7° | Right: 157.0°
Arms Position
94%
Angle symmetry: 94% | Swing: 88%
Recommendations
Focus on maintaining equal knee flexion between both legs during the stance phase
Work on hip alignment - ensure both hips remain level throughout the running cycle

SymStride Real-time Running Form Symmetry Analysis

Dashboard | Joint Angles | Asymmetry Metrics | Feedback

○ Offline

Joint Angle Analysis

Real-time monitoring of joint angles to detect asymmetries in running form

Knee Angles

LEFT	vs	RIGHT
165.6°		164.6°

Symmetry: 99%

Hip Angles

LEFT	vs	RIGHT
170.4°		169.7°

Symmetry: 100%

Ankle Angles

LEFT	vs	RIGHT
110.3°		109.7°

Symmetry: 99%

Joint Angle Over Time

SymStride Real-time Running Form Symmetry Analysis

Dashboard | Joint Angles | Asymmetry Metrics | Feedback

○ Offline

Overall Asymmetry Score

0.8%

LOW ASYMMETRY

Lower scores indicate better symmetry. Aim for < 2% asymmetry.

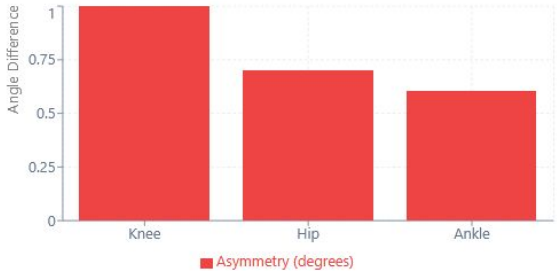
Symmetry Breakdown

Knee LOW
Asymmetry: 1.0° Symmetry: 99%

Hip LOW
Asymmetry: 0.7° Symmetry: 100%

Ankle LOW
Asymmetry: 0.6° Symmetry: 99%

Angle Asymmetry by Joint



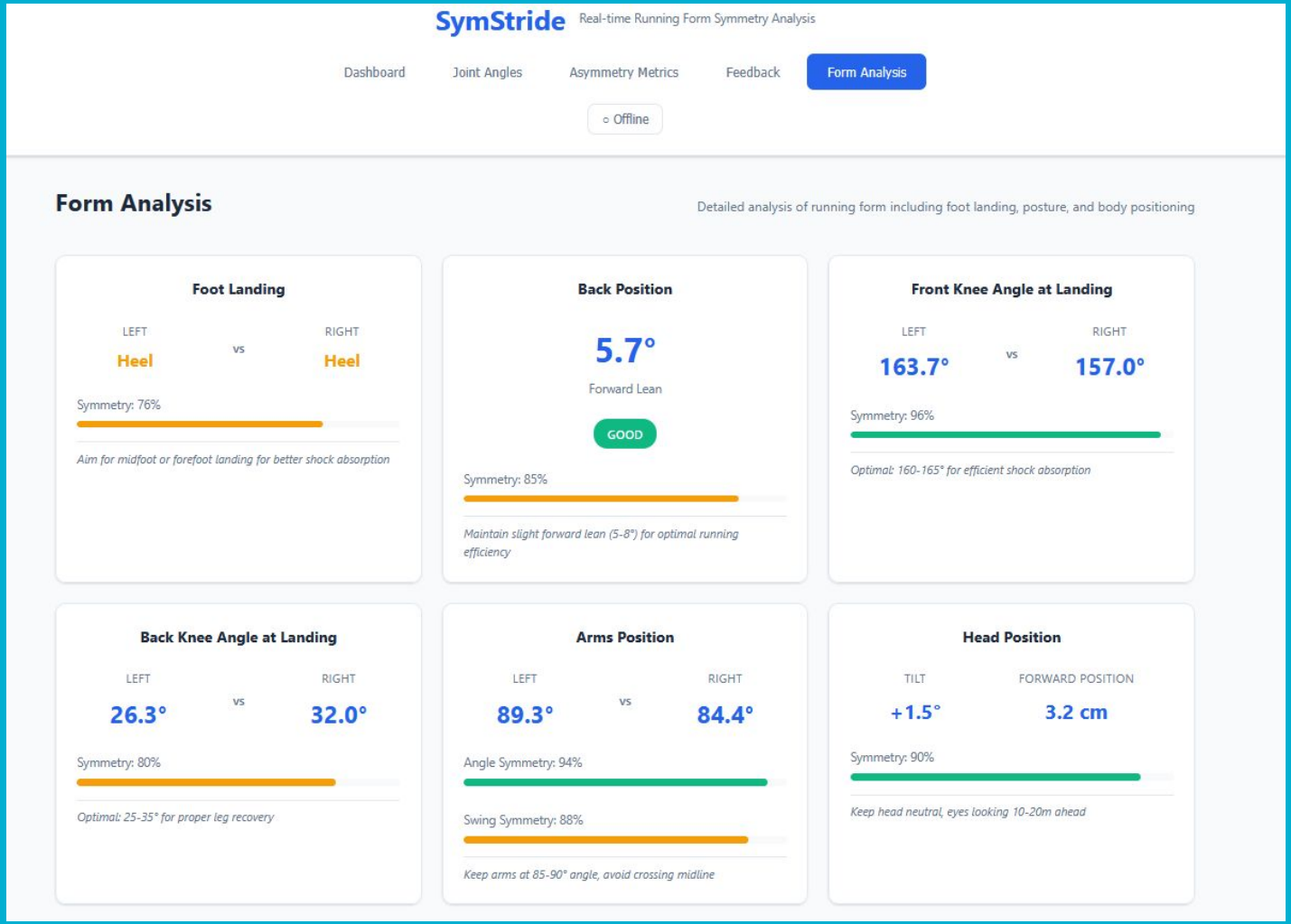
Symmetry Radar Chart

Key Insights

Knee Angle Asymmetry Detected

Hip Alignment is Good

Ankle Symmetry Improving


SymStride
Real-time Running Form Symmetry Analysis
Dashboard
Joint Angles
Asymmetry Metrics
Feedback
Form Analysis
Offline
Form Analysis
Detailed analysis of running form including foot landing, posture, and body positioning
Foot Landing
LEFT
Heel
vs
RIGHT
Heel
Symmetry: 76%
Aim for midfoot or forefoot landing for better shock absorption
Back Position
5.7°
Forward Lean
GOOD
Symmetry: 85%
Maintain slight forward lean (5-8°) for optimal running efficiency
Front Knee Angle at Landing
LEFT
163.7°
vs
RIGHT
157.0°
Symmetry: 96%
Optimal: 160-165° for efficient shock absorption
Back Knee Angle at Landing
LEFT
26.3°
vs
RIGHT
32.0°
Symmetry: 80%
Optimal: 25-35° for proper leg recovery
Arms Position
LEFT
89.3°
vs
RIGHT
84.4°
Angle Symmetry: 94%
Swing Symmetry: 88%
Keep arms at 85-90° angle, avoid crossing midline
Head Position
TILT
+1.5°
FORWARD POSITION
3.2 cm
Symmetry: 90%
Keep head neutral, eyes looking 10-20m ahead