Pickleball Biomechanics: The ML Advantage

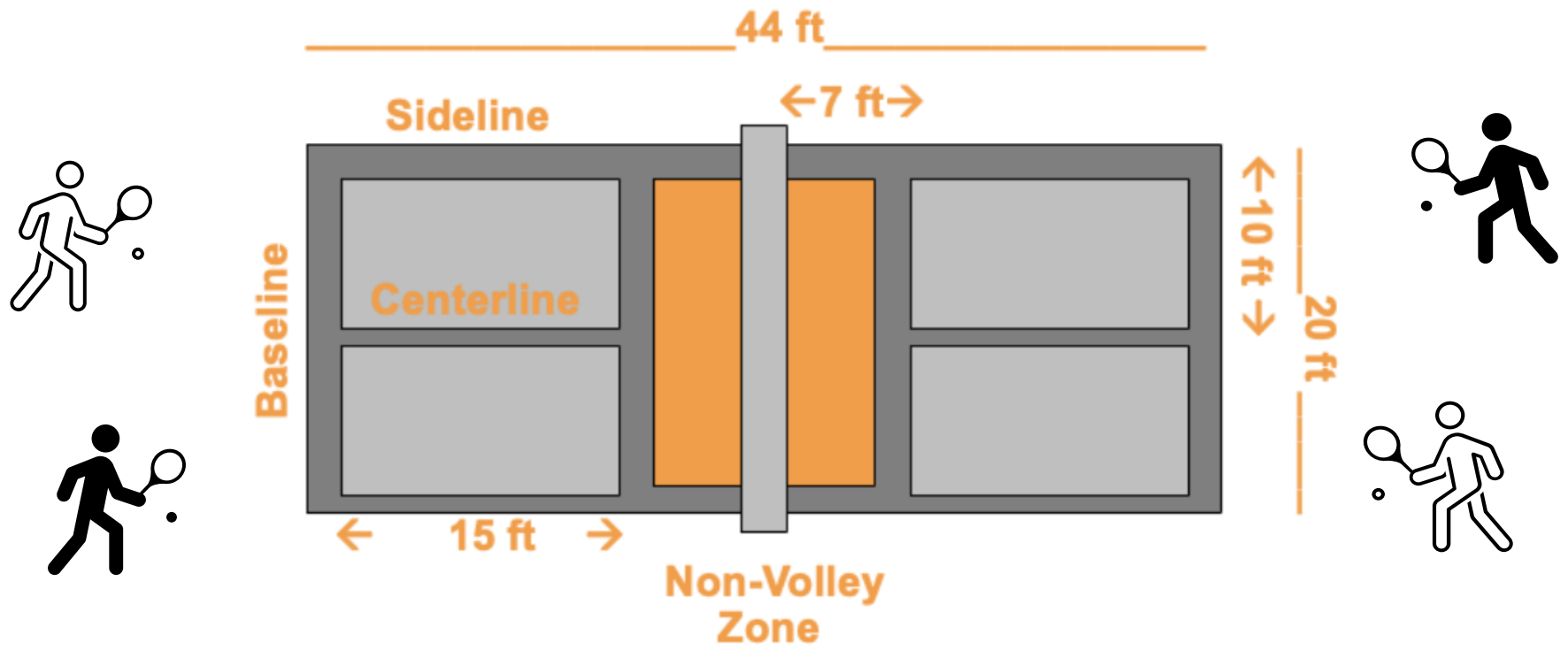
Presenter: Thomas Young

THE UNIVERSITY OF TENNESSEE KNOXVILLE

Young T.; Kalchbrenner, L.; Mink, T.; Allen, A.; Tatarski, R

Road Map

What is Pickleball?



2024[1]

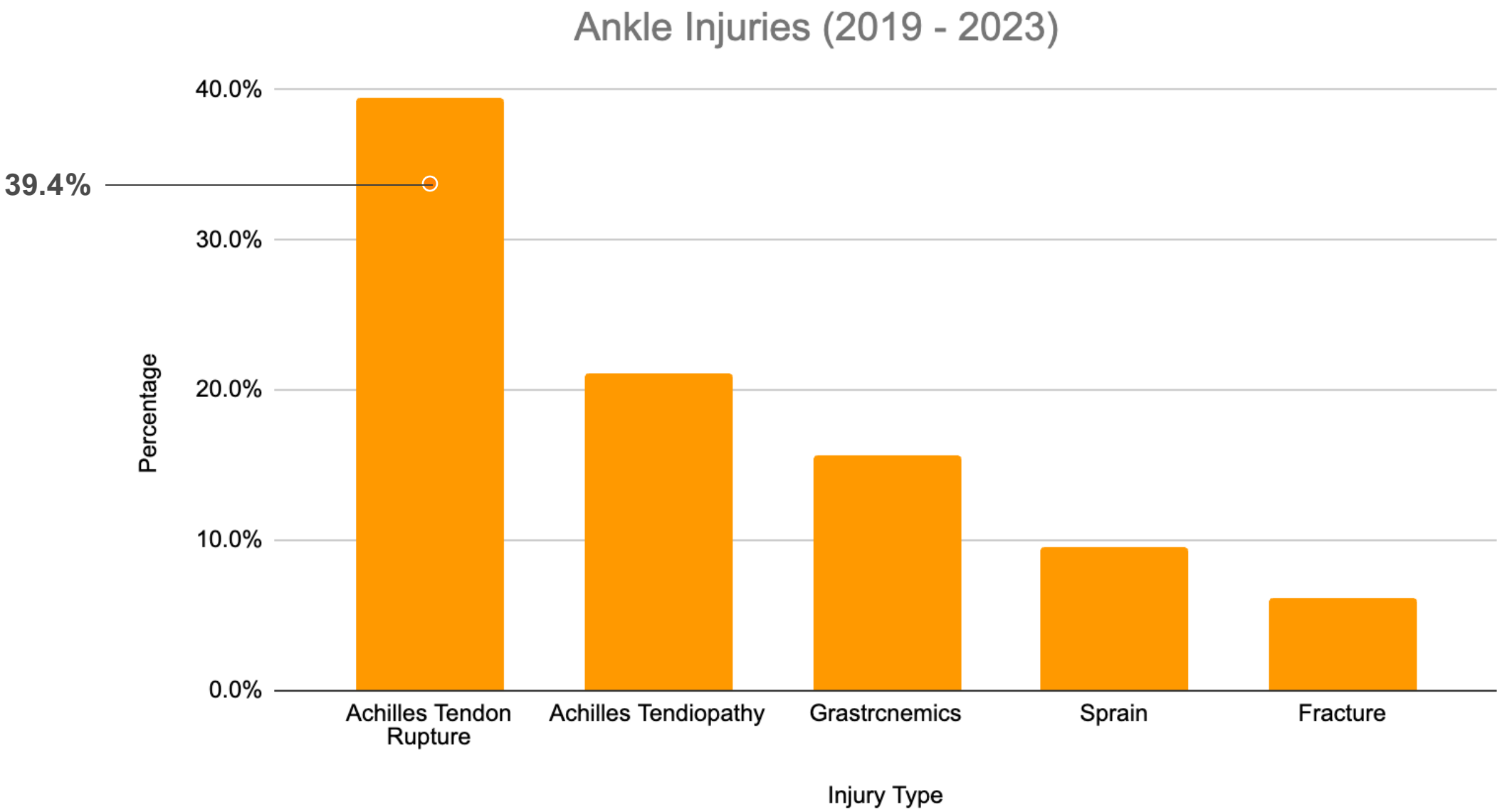
19.8 Million Players

311% growth since 2022

33.5% of players are 25-34

40%[2]

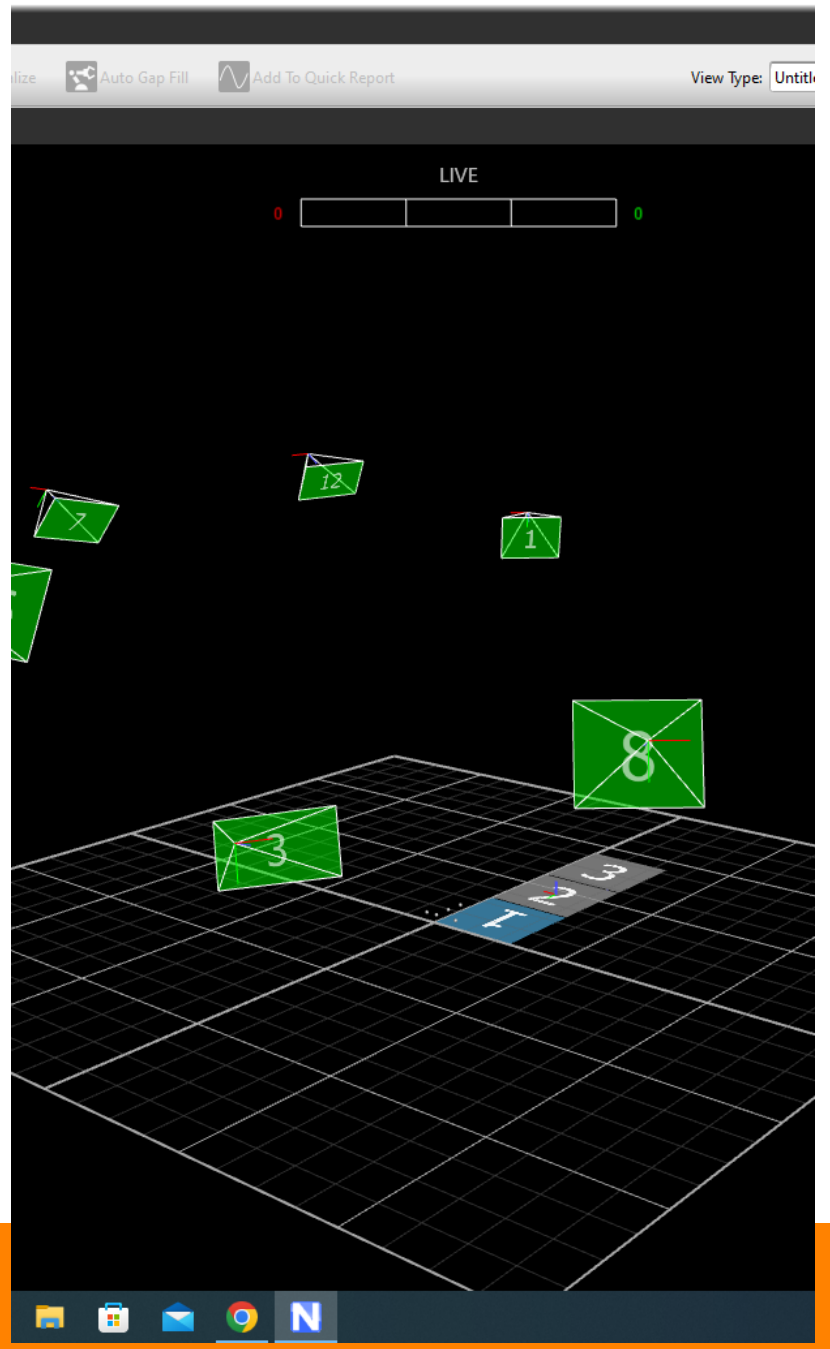
Achilles Tendon Ruptures

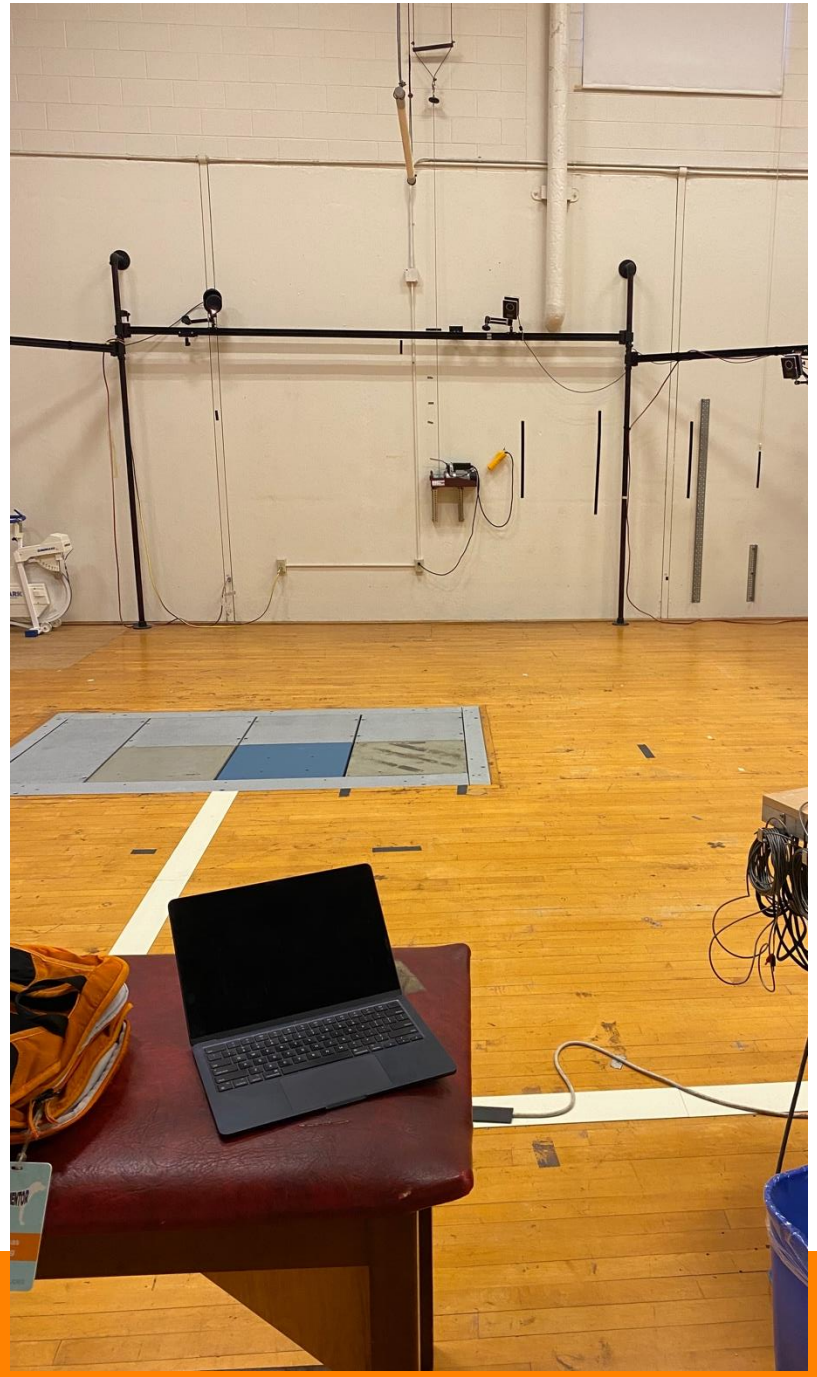

Ankle Injuries (2019 - 2023)
39.4%
40.0%
30.0%
20.0%
10.0%
0.0%
Percentage
Achilles Tendon Rupture
Achilles Tendiopathy
Grastrcnemics
Sprain
Fracture
Injury Type

Research Question

- Research Question
  - What is the effect of acute ankle stretching protocol on ankle biomechanics during cutting maneuvers for young adults?

- Machine Learning Question
  - Do biomechanical subgroups, based on pre- and post-pickleball movement ankle range of motions, emerge with distinct demographic profiles?


Auto Gap Fill
Add To Quick Report
View Type:
LIVE
0
0
12
7
1
8
3
1
2
3



Methods

- Within Subject
- Two day event
  - Day 1 - Baseline
  - Day 2 - Stretching intervention
- Captured Static Range of Motion

Figure 1: Straight leg stretch at 30 degrees dorsiflexion (4 X 30 seconds)

Figure 2: Flexed leg stretch at 30 degrees dorsiflexion (4 X 30 seconds)

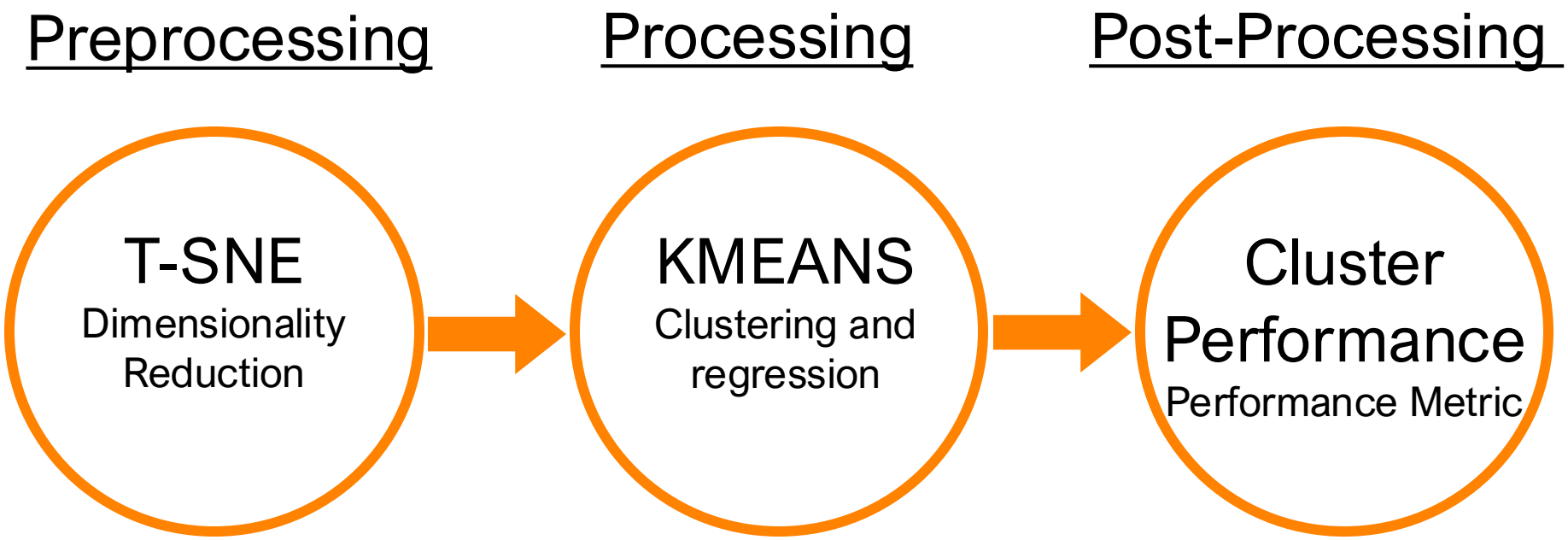
Participants

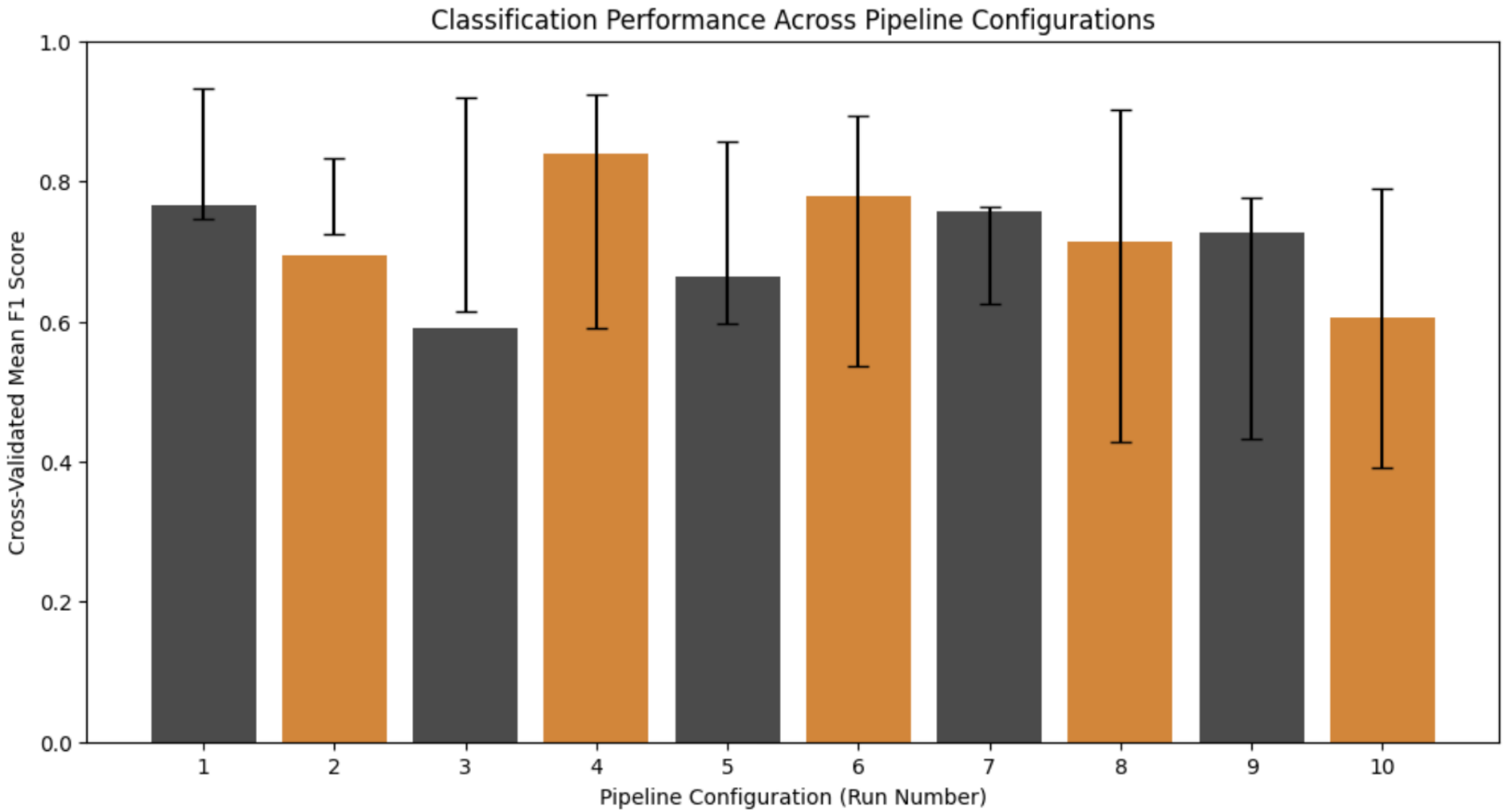
- Data is paired
  - Every subject has a pre - post for same day
- Normally distributed
  - Day 1: N = 29
  - Day 2: N = 29

Variable	Average	SD
Age	33.03	16.16
Height	1.73	0.10
Gender	0.58	0.10
Shoe Size	9.41	1.79
Leg Dominance	0.13	0.35
Arm Dominance	0.13	0.35
# of times playing	0.62	0.49

Table 1: Age in years, Height in meters, Gender with 0 as female and male as 1, Dominance with 0 as right and 1 as left, # of times playing with 0 casual and 1 as core player. Refer to code book

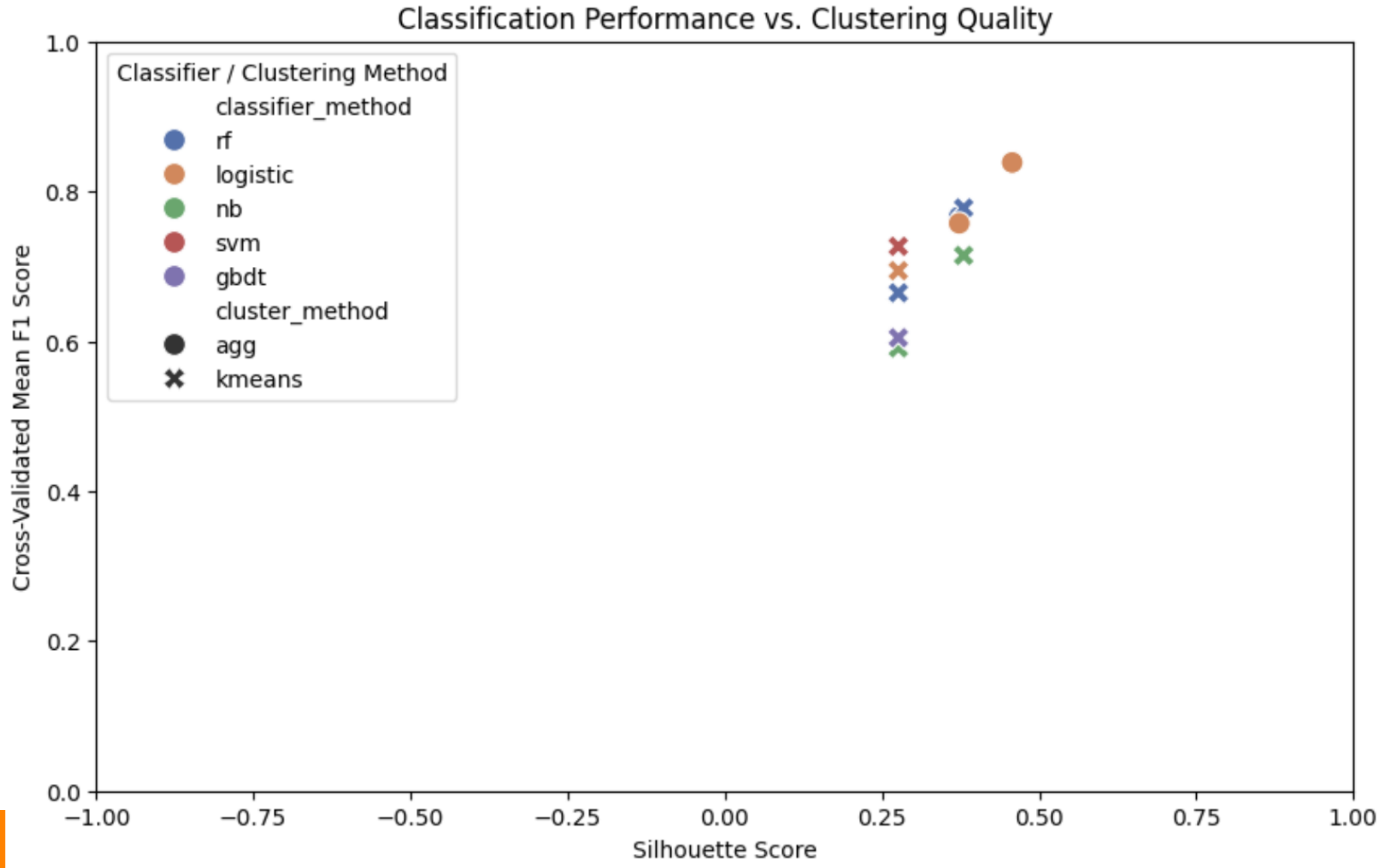
Workflow

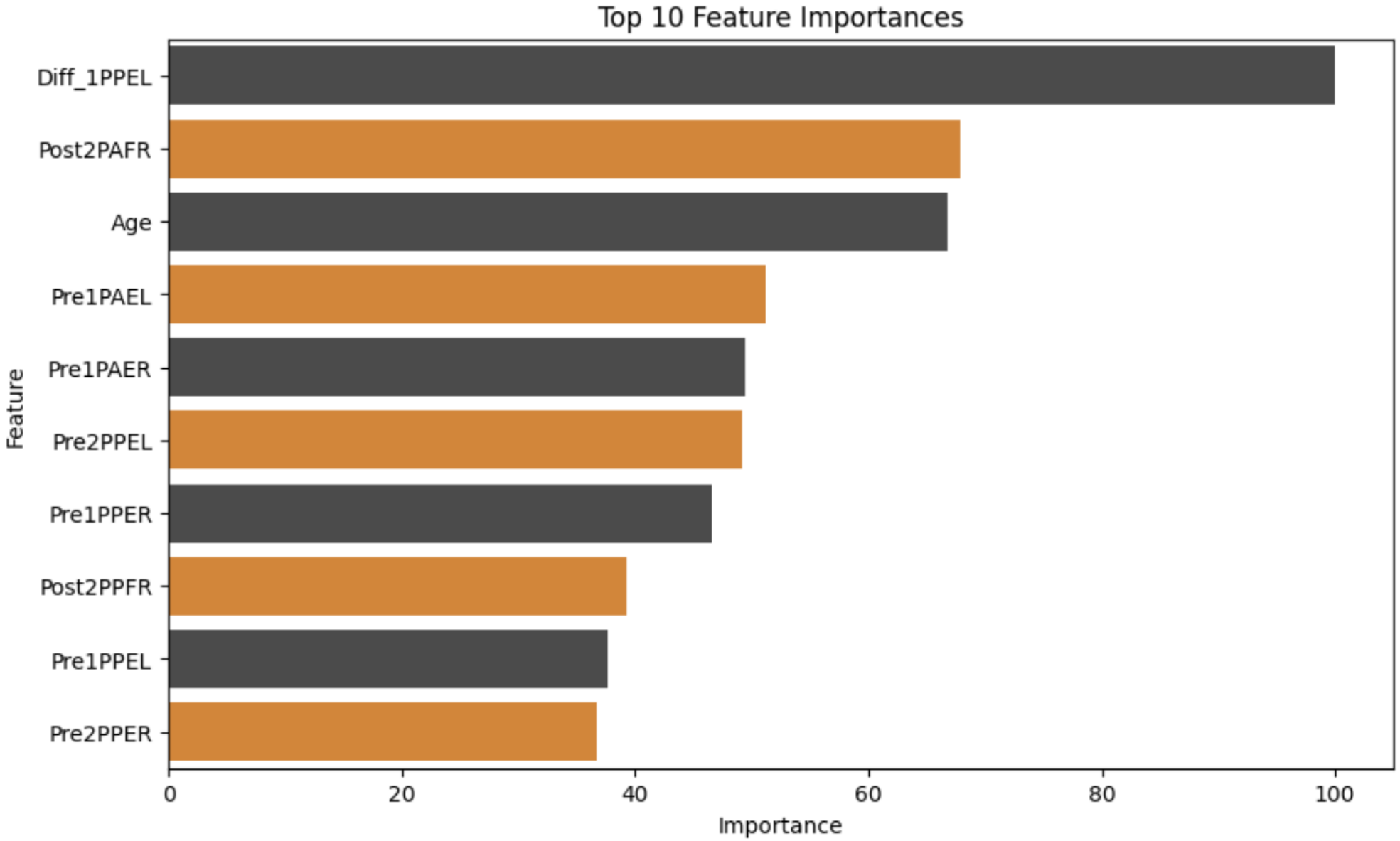

Preprocessing
Processing
Post-Processing
T-SNE
Dimensionality Reduction
KMEANS
Clustering and regression
Cluster Performance
Performance Metric

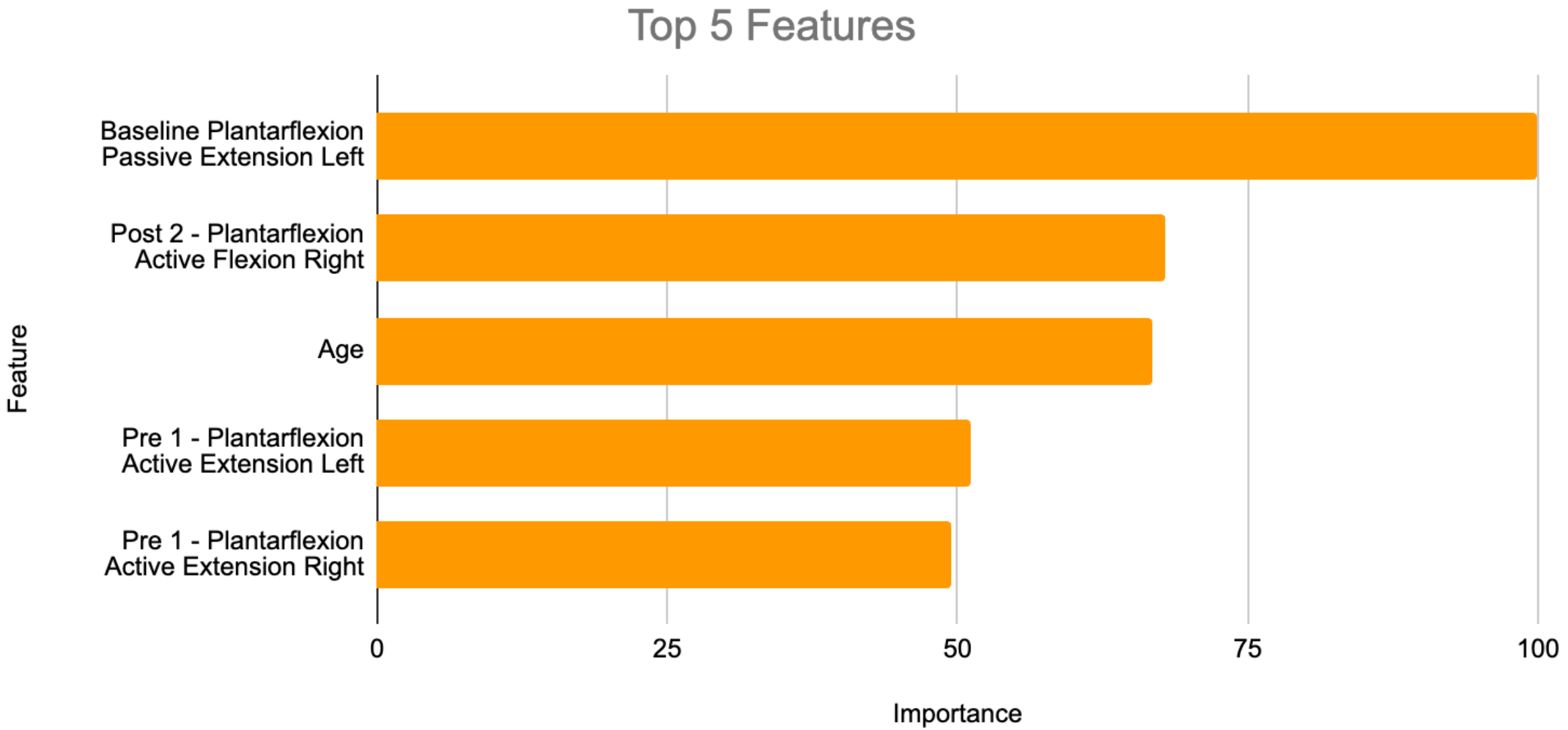

Classification Performance Across Pipeline Configurations
Cross-Validated Mean F1 Score
1.0
0.8
0.6
0.4
0.2
0.0
1
2
3
4
5
6
7
8
9
10
Pipeline Configuration (Run Number)

Pipelines

Run 1: t-SNE Only + Agglomerative Clustering + Random Forest + Feature Selection
Run 2: PCA + t-SNE + KMeans + Logistic Regression + Feature Selection
Run 3: PCA + t-SNE + KMeans + Naive Bayes + Feature Selection
Run 4: PCA + t-SNE + Agglomerative Clustering + Logistic Regression + Feature Selection
Run 5: Fusion: PCA + t-SNE + KMeans + Voting Classifier (RF, NB, Logistic) + Feature Selection
Run 6: t-SNE Only + KMeans + Random Forest + Feature Selection
Run 7: t-SNE Only + Agglomerative Clustering + Logistic Regression + Feature Selection
Run 8: t-SNE Only + KMeans + Naive Bayes + Feature Selection
Run 9: t-SNE + PCA + KMeans + SVM + Feature Selection
Run 10: t-SNE + PCA + KMeans + GBDT + Feature Selection


Classification Performance vs. Clustering Quality
Classifier / Clustering Method
classifier_method
rf
logistic
nb
svm
gbdt
cluster_method
agg
kmeans
Cross-Validated Mean F1 Score
1.0
0.8
0.6
0.4
0.2
0.0
−1.00
−0.75
−0.50
−0.25
0.00
0.25
0.50
0.75
1.00
Silhouette Score

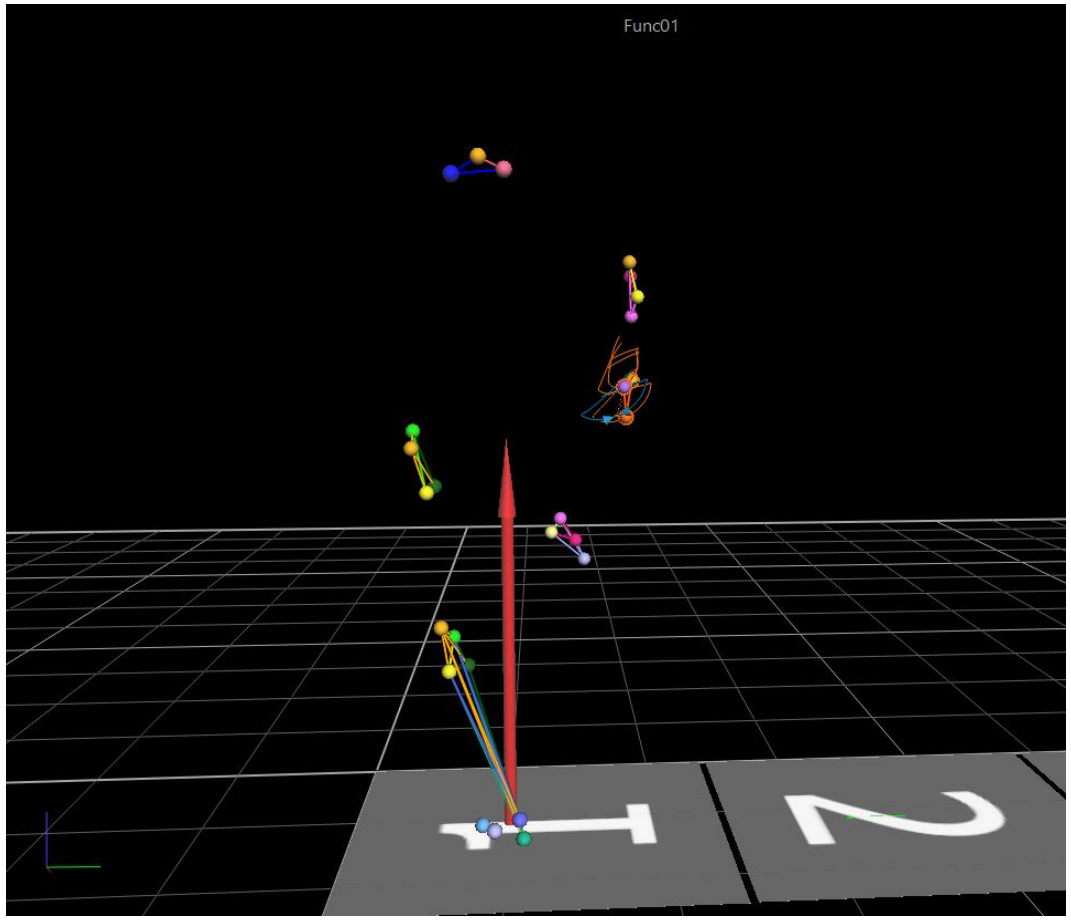
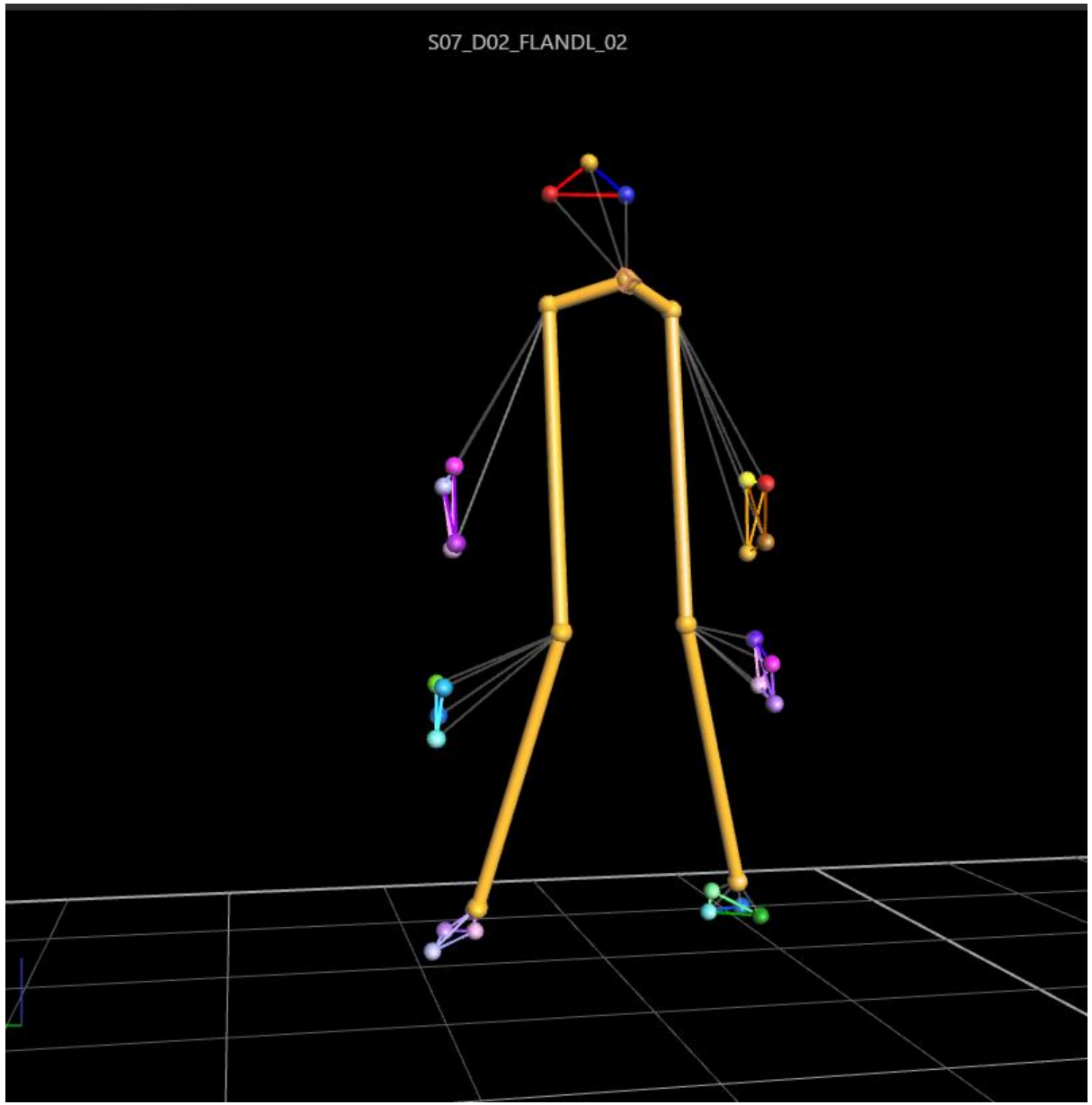

Top 10 Feature Importances
Diff_1PPEL
Post2PAFR
Age
Pre1PAEL
Pre1PAER
Pre2PPEL
Pre1PPER
Post2PPFR
Pre1PPEL
Pre2PPER
Feature
0
20
40
60
80
100
Importance


Top 5 Features
Baseline Plantarflexion Passive Extension Left
Post 2 - Plantarflexion Active Flexion Right
Age
Pre 1 - Plantarflexion Active Extension Left
Pre 1 - Plantarflexion Active Extension Right
Feature
0
25
50
75
100
Importance

Findings

- Baseline ankle ROM was a strong predictor of how an individual's ankle ROM will change after pickleball movements and stretching.
- Those with limited initial flexibility might be more prone to changes / improvements with the intervention.
- Age, since range was between 18 and 80 years old, was an important feature that separated clusters.
- Post2 features might indicate that the stretching intervention has the potential to improve specific aspects of ankle ROM that are relevant to pickleball performance / injury risk.

References

1. 2025 SFIA Topline Report.
2. Kingston K, Parker EB, Higgins A, Smith JT. Epidemiology of Pickleball-Related Foot and Ankle Injuries (2015 – 2023). Foot Ankle Orthop. 2024;9(4). doi:10.1177/24730114 24S00272

Thank You!