SPORTS FIELD MANAGEMENT ASSOCIATION

New Approaches for Testing Sports Field Safety and Performance

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New Approaches for Testing Sports Field Safety and Performance

Gerald Henry, PhD and Erick Begitschke
University of Georgia

SFMA
GEORGIA SPORTS FIELD MANAGEMENT ASSOCIATION

TEAM UGA

Equipment Advances

Rule Changes

Surface and Profile Advances

Management and Equipment Improvements

Injuries Still Occur

Better understand player/field interactions

Athletic Field Performance Testing

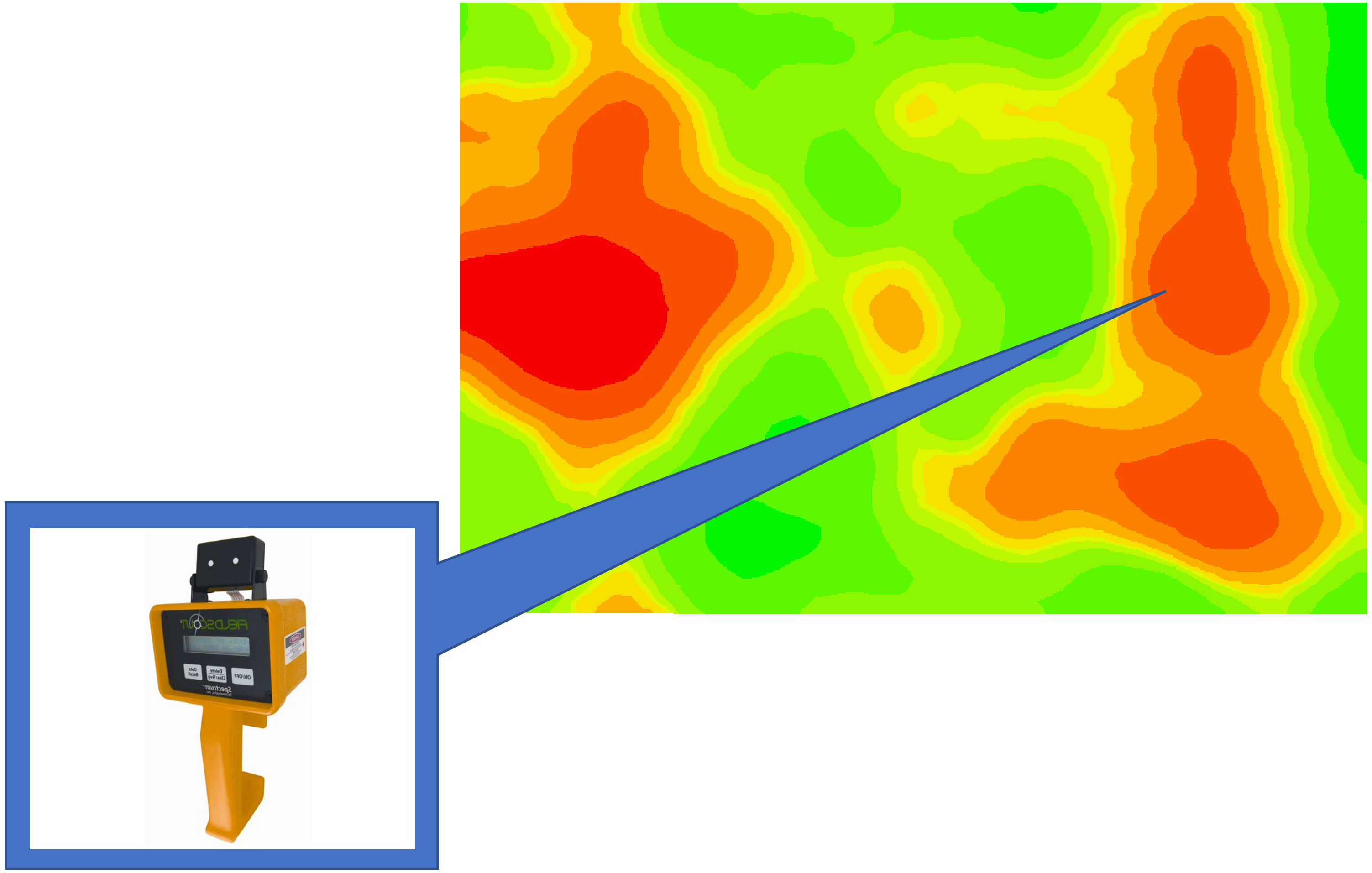
- Research progression at the University of Georgia
  - In depth field assessments
  - Long-term player/surface interaction trends
  - Real-time player monitoring
    - Field vs laboratory evaluations

In Depth Field Assessments

- Identify key plant and soil parameters
- Accurately describe field characteristics
- Determine interactions between field components
- Describe the impact on turfgrass rooting/canopy

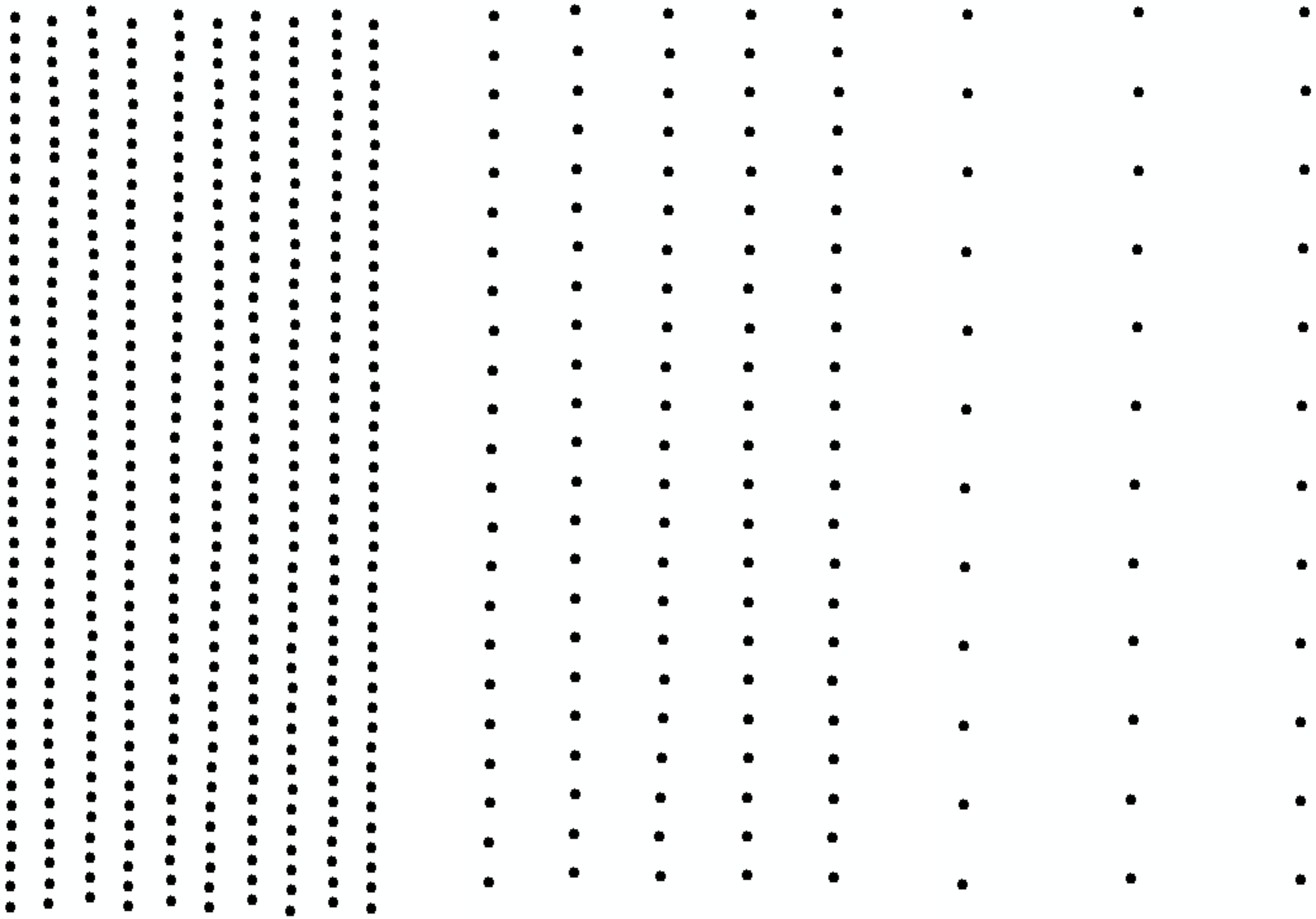
Measurable Variables

- Soil Moisture
- Soil Compaction
- Surface Hardness
- Turfgrass Health
- Shear Strength
- Turfgrass Thatch



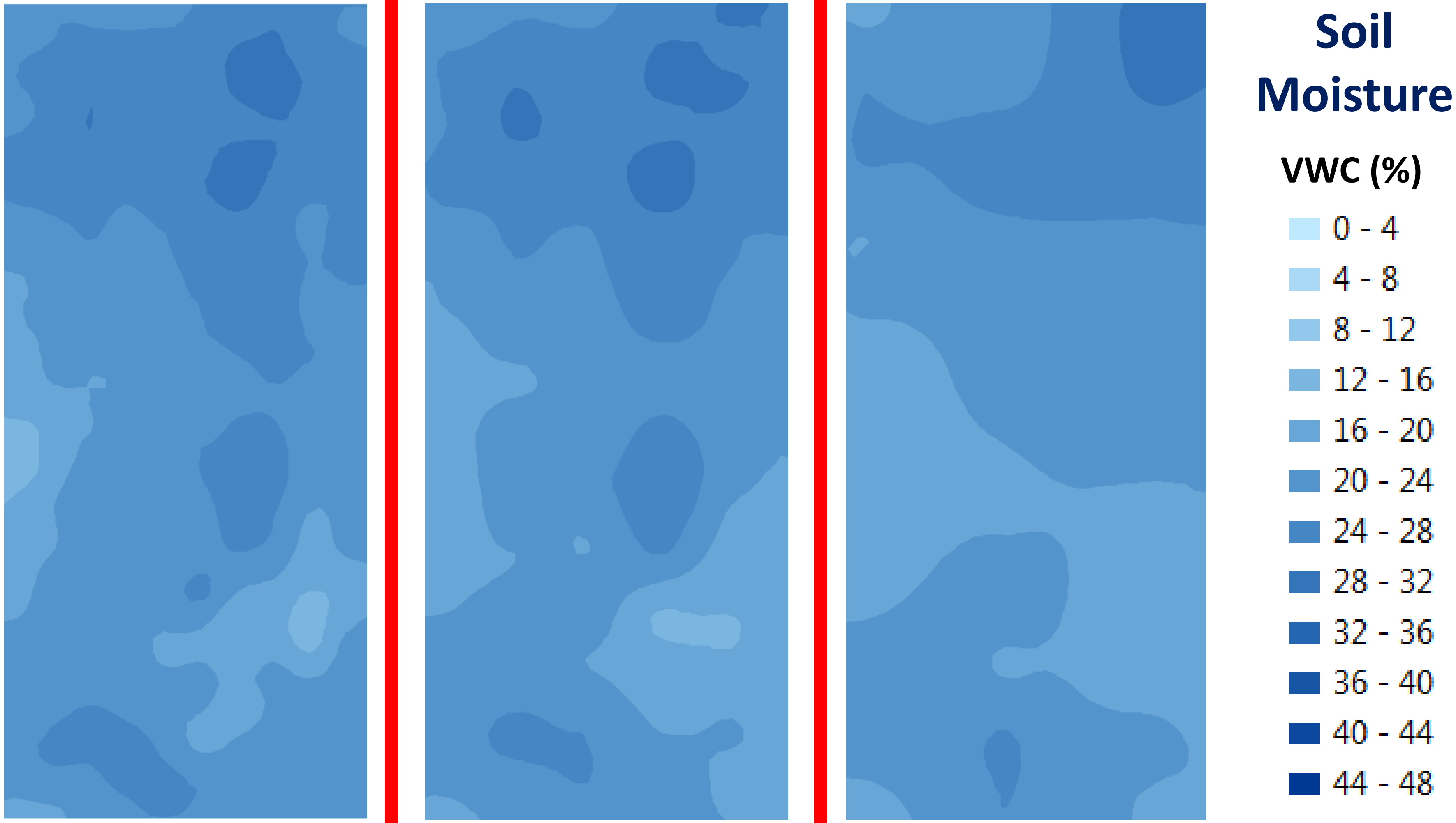
Accurately Describe Field Characteristics

450 Samples **115 Samples** **36 Samples**



Accurately Describe Field Characteristics

450 Samples	115 Samples	36 Samples
Mean = 22.9	Mean = 22.7	Mean = 21.5



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Agrosystems, Geosciences & Environment
OPEN ACCESS

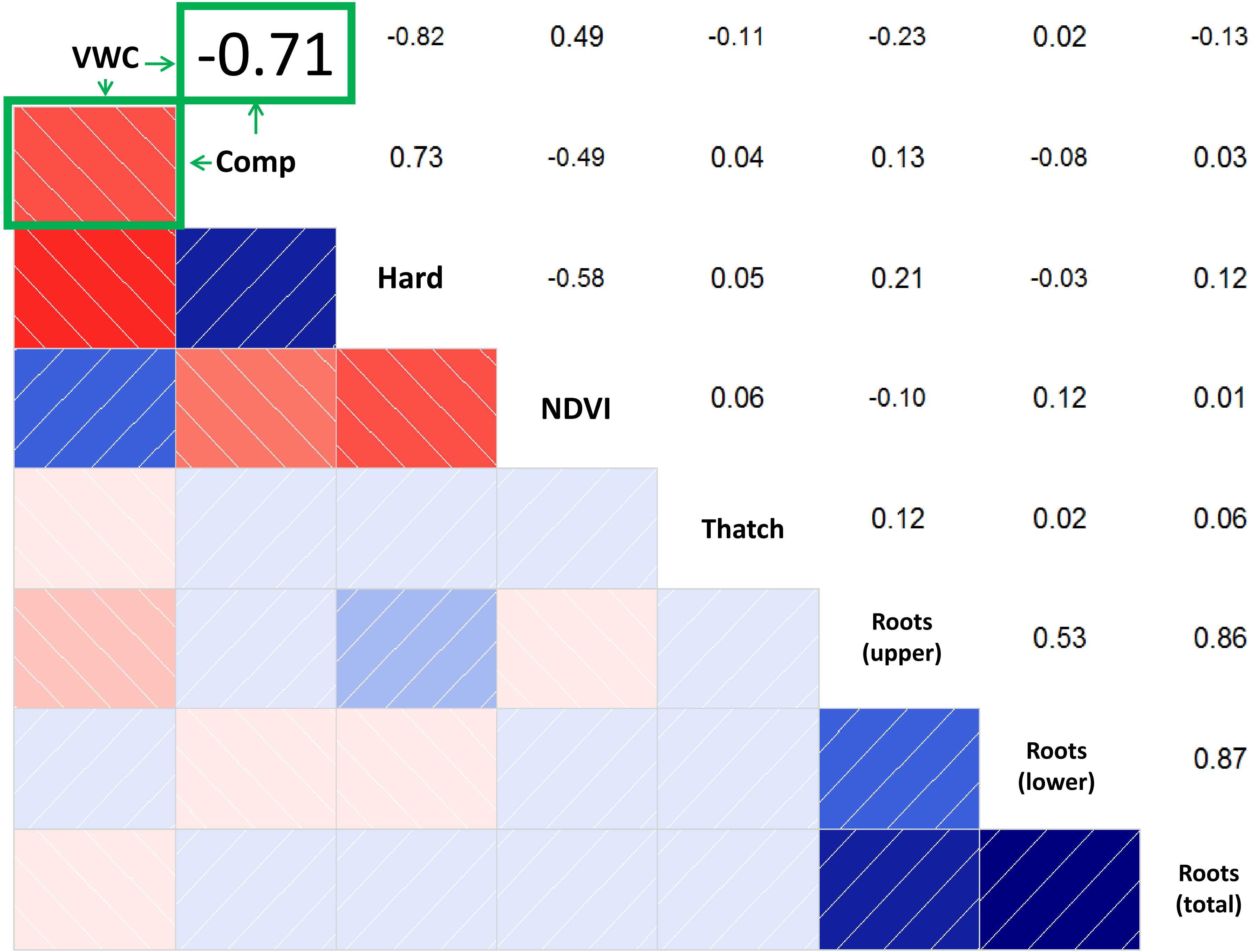
ORIGINAL RESEARCH ARTICLE

Geosciences

Short-term spatiotemporal relationship between plant and soil properties on natural turfgrass sports fields

Chase M. Straw[1] | Rebecca A. Grubbs[2] | Gerald M. Henry[3]

- Soil parameters and their interactions influence root mass and depth
- Management that accounts for spatial relationships can improve uniformity of field properties


VWC
-0.71
-0.82
0.49
-0.11
-0.23
0.02
-0.13
Comp
0.73
-0.49
0.04
0.13
-0.08
0.03
Hard
-0.58
0.05
0.21
-0.03
0.12
NDVI
0.06
-0.10
0.12
0.01
Thatch
0.12
0.02
0.06
Roots (upper)
0.53
0.86
Roots (lower)
0.87
Roots (total)

Taylor & Francis

European Journal of Sport Science

2018

ISSN: 1746-1391 (Print) 1536-7290 (Online) Journal homepage: http://www.tandfonline.com/loi/tejs20

Does variability within natural turfgrass sports fields influence ground-derived injuries?

Chase M. Straw, Christine O. Samson, Gerald M. Henry & Cathleen N. Brown

- Long-term player/surface interaction trends – 2 years
- Men's and Women’s Rugby, Ultimate Frisbee, Soccer, and Lacrosse

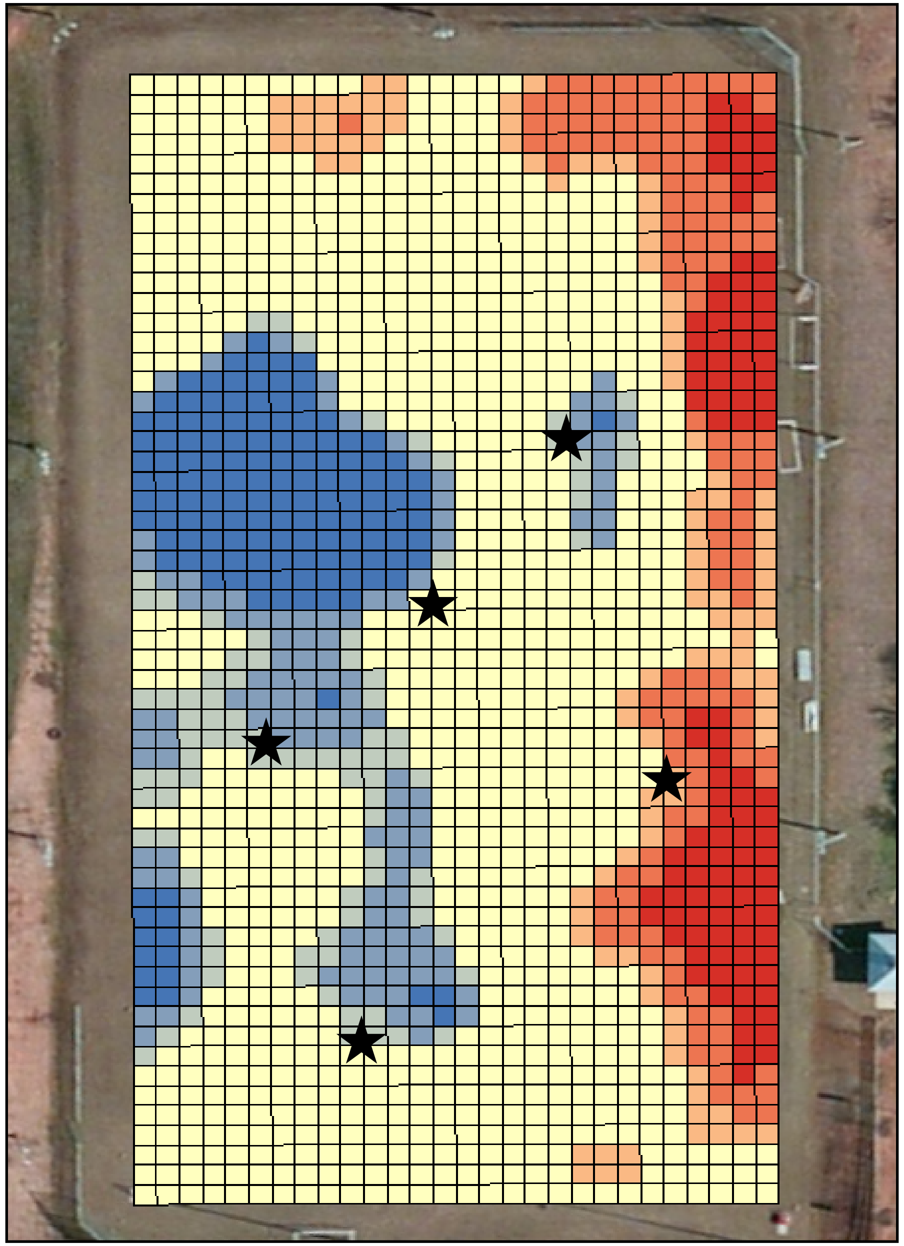
Field Measurements

Weekly:

- Soil moisture
- Turf quality (NDVI)

Bi-weekly:

- Surface hardness
- Shear strength



Injuries in Hot/Cold Spots

- Soil moisture (15/19 injuries; 79%)
- Turfgrass quality (16/21 injuries; 76%)
- Surface hardness and turfgrass shear strength (13/23 injuries; 57%)

*** 70 to 88% of injuries occurred at edge of differing conditions**

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Does variability within natural turfgrass sports fields influence ground-derived injuries?

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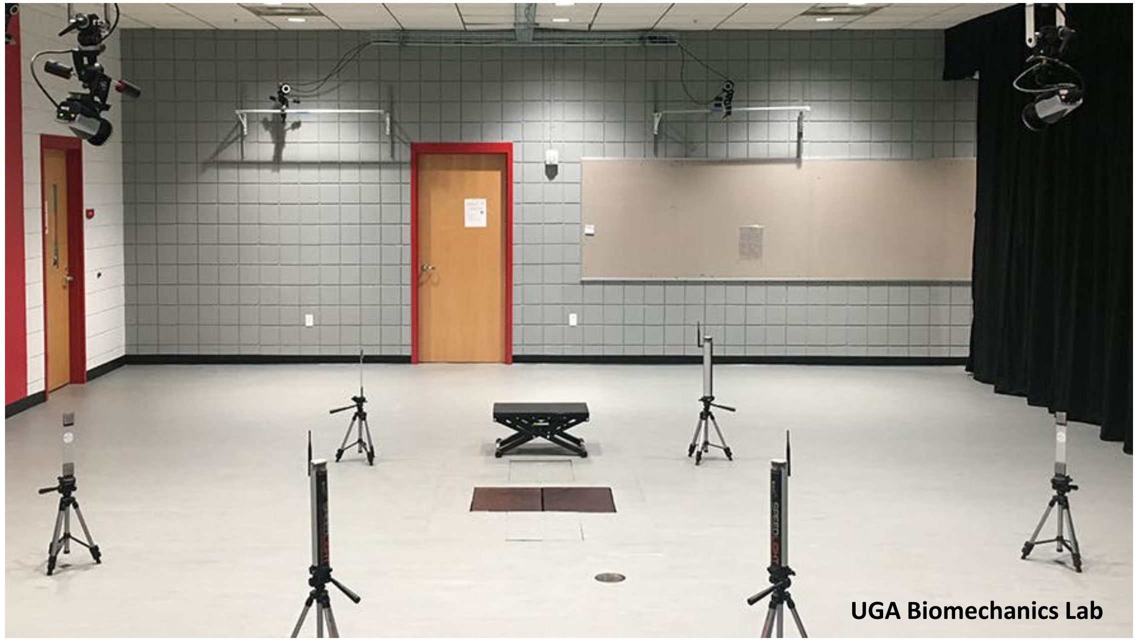
- Although correlations were made between field conditions and injuries, “real time” data is still necessary to accurately depict field influence

Previous Research

- Research relating field conditions and athlete performance/injuries has primarily been in situ

- Athlete biomechanics research has been primarily laboratory-based

Sports Fields Management



UGA Biomechanics Lab

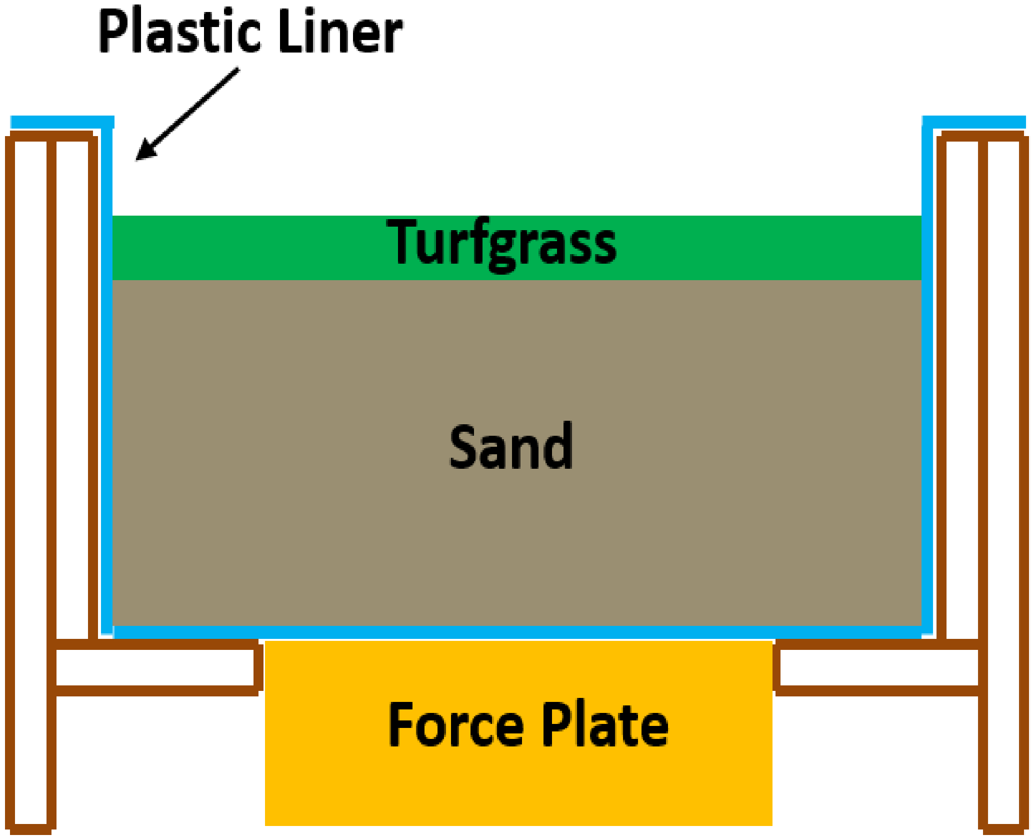
Biomechanics Research

- Biomechanics laboratories are often equipped with force plates and three-dimensional motion capture systems
  - Precise measurements of athlete kinematic and kinetic movement
- However, these laboratories are often limited by space and conditional versatility
  - Difficult to simulate real-world athletic movements
  - Neglects interactions with the field

Force plate

Ground Reaction Platforms

Vertical Force Data



Determine the impact of field surfaces plus underlying soil profiles on athlete performance

Ground Reaction Platforms

Potential use:

- Natural turfgrass vs. artificial turf
- Profile characteristics – compaction, moisture
- Profile materials – sand, soil
- Turfgrass species and cultivars
- Mixed species – hybrid systems, weeds


Plastic Only
USGA Spec Sand
Sandy clay loam
BRUTE

0.5 inch mowing height

Materials and Methods

Athens Turfgrass Research
and Education Center

GRP Proof of Concept Study

- ‘Ironcutter’ hybrid bermudagrass
- Native soil vs sand-based systems
- 10-cm soil profile vs 15-cm soil profile

Data Collection

- One healthy 175 cm, 80.7 kg, 20-year-old male participant
- Participant fitted with an IMU on thigh and shank of non-dominant leg
- Three trials of four athletic maneuvers on GRPs and force plate alone
  - Jump landing (JL)
  - Drop landing (DL)
  - Single-leg drop landing (SLD)
  - Counter-movement jump (CMJ)


BENDPAK

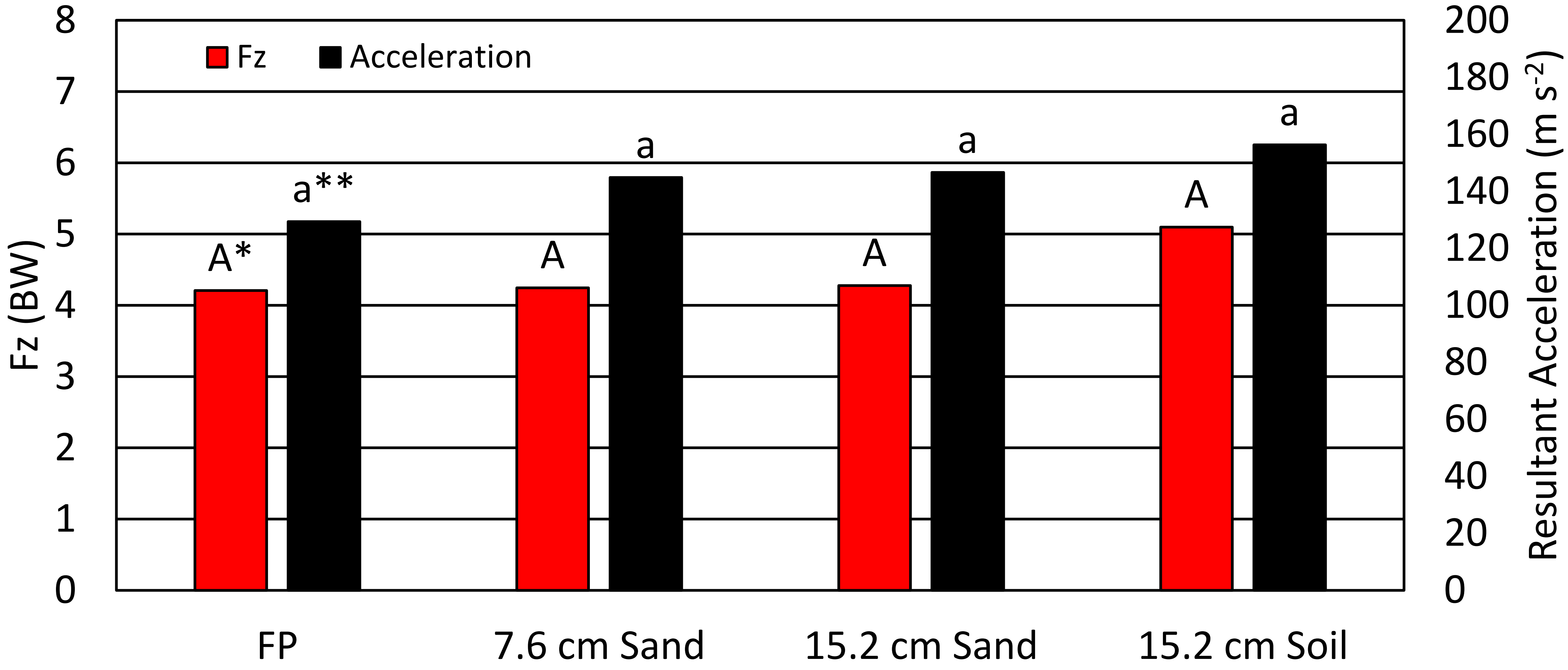
Response Variables

- Peak vertical force (Fz) determined by force plate for each trial of each maneuver
  - Data normalized by measuring the static force of the participant on each GRP
  - Reported in bodyweights (BWs)
- Peak thigh and shank resultant accelerations determined by attached IMUs
  - Resultant acceleration = magnitude of accelerations measured in the x, y, and z axes

Results

Athens Turfgrass Research and Education Center

CMJ Peak Vertical Ground Reaction Force and Resultant Acceleration



*Fz $LSD_{0.05}$ = 1.52 BWs

**Resultant Acceleration $LSD_{0.05}$ = 34.11 m s^{-2}

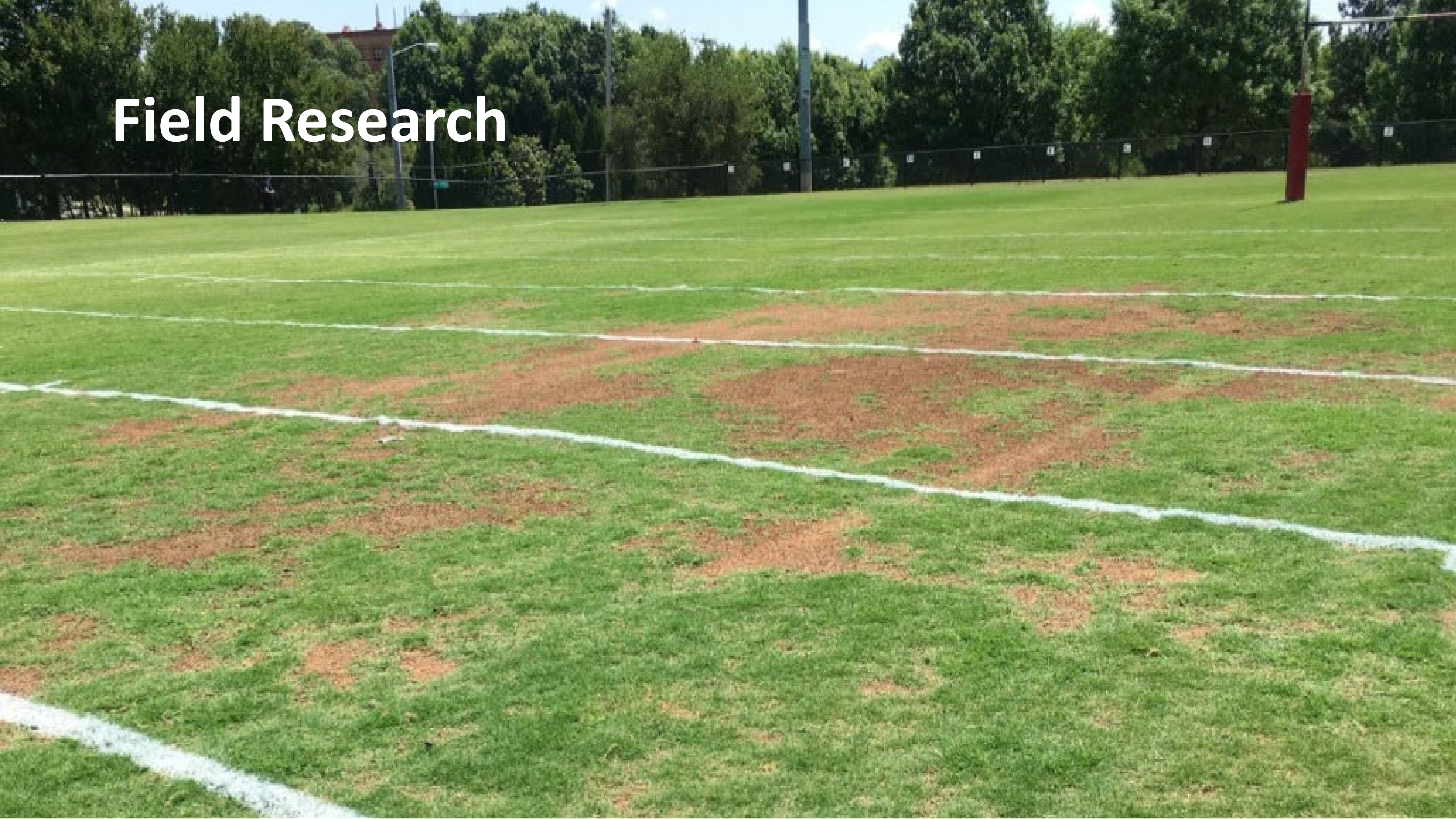
Discussion and Conclusions

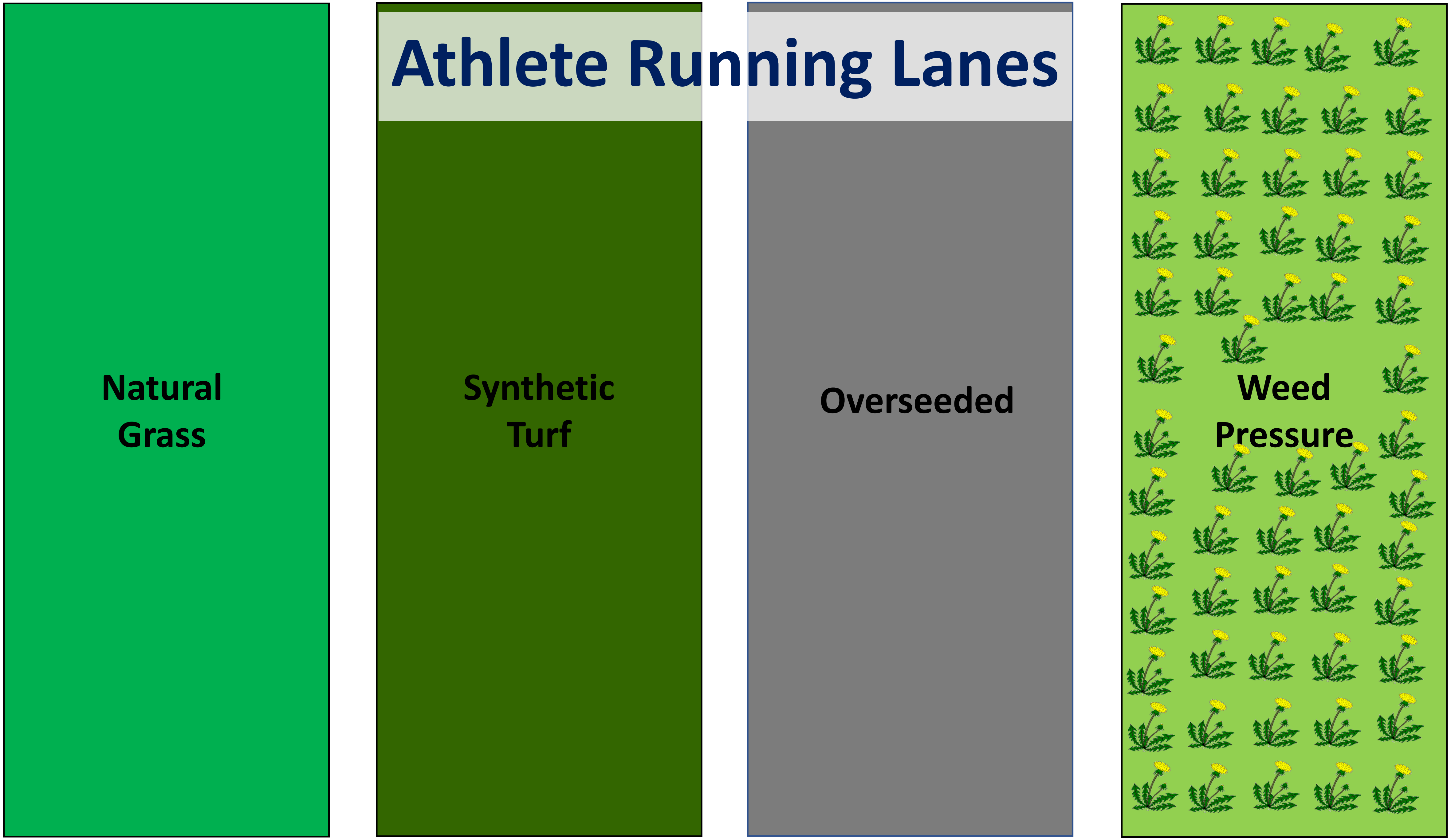
- CMJ can effectively compare different surfaces/profiles with GRPs
- However, GRPs influenced the force plate measurements for all other maneuvers
- Difficulties faced during construction and testing:
  - GRPs are extremely heavy
  - Compacting the soil properly without damaging the GRP
  - Fracturing of soil when placing on force plate

Future Research

- Improve GRP design to account for difficulties during testing
  - Conduct drop tests on smaller GRPs with custom-built force plates
- Use IMUs to measure vertical and horizontal accelerations on GRPs and **in the field**
  - Biomechanical research has shown correlations between vertical accelerations and ground reaction force

Field Research




Athlete Running Lanes
Natural Grass
Synthetic Turf
Overseeded
Weed Pressure

Athlete Running Lanes

May 24, 2023

Athlete Running Lanes

September 22, 2023

Bringing the Lab into the Field

- Higher vertical ground reaction forces and lower leg vertical accelerations associated with elevated injury risk
- Vertical ground reaction force data difficult to measure in the field
- Lower leg vertical acceleration parameters serve as alternatives to vertical ground reaction force data
  - Force is derived from acceleration measurements using $F = m \times a$

Takeoff

Horizontal Force Data

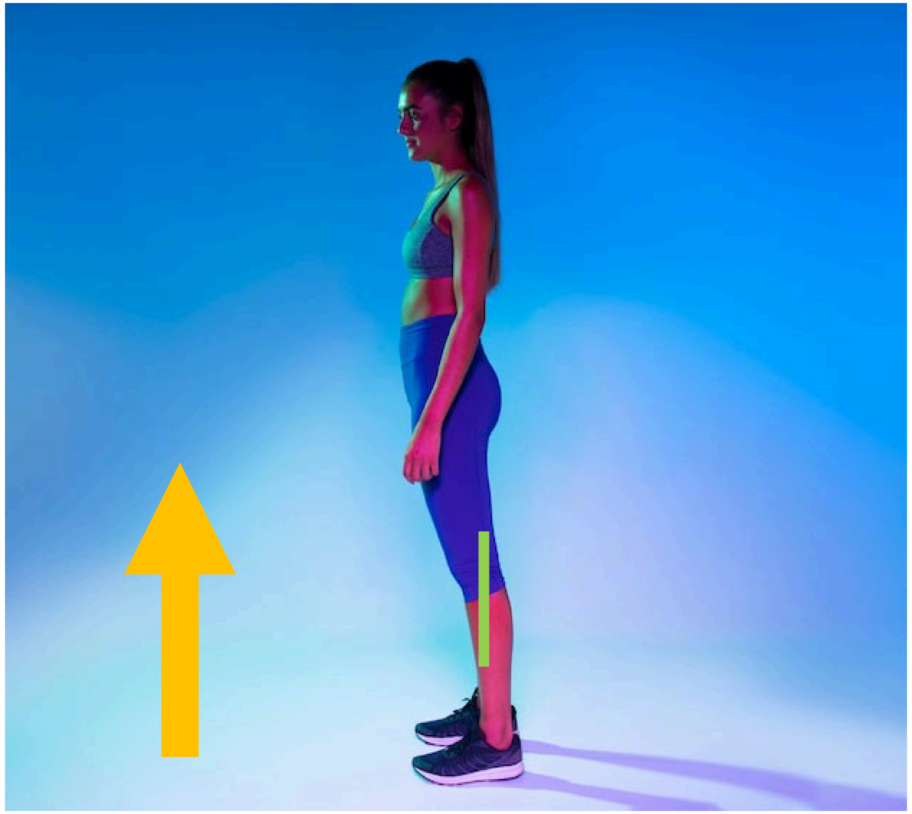
Cutting

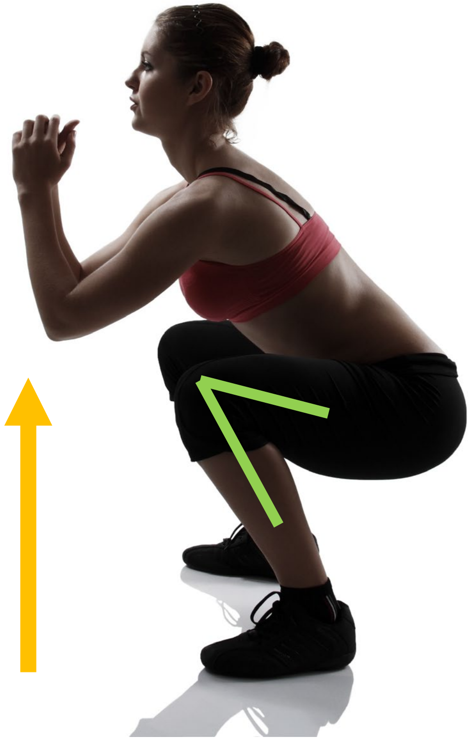
Injury Prevention

- Athletes are trained to land with increased knee flexion to decrease knee strain and prevent injuries
- Surface characteristics influence knee flexion angles when landing
- Combining knee flexion angle and tibial acceleration data may reveal a new way to evaluate playing surface safety

Injury Prevention

High Returned Force Low



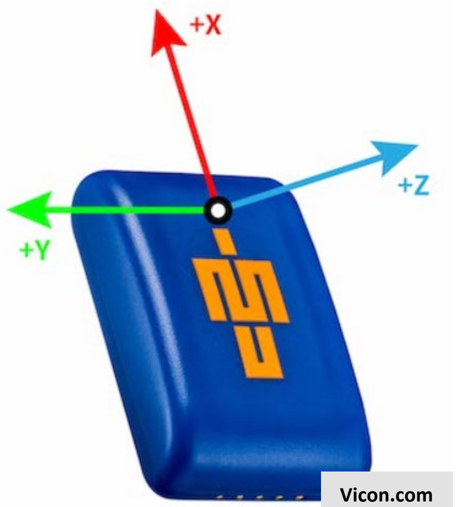


Low Knee Flexion High

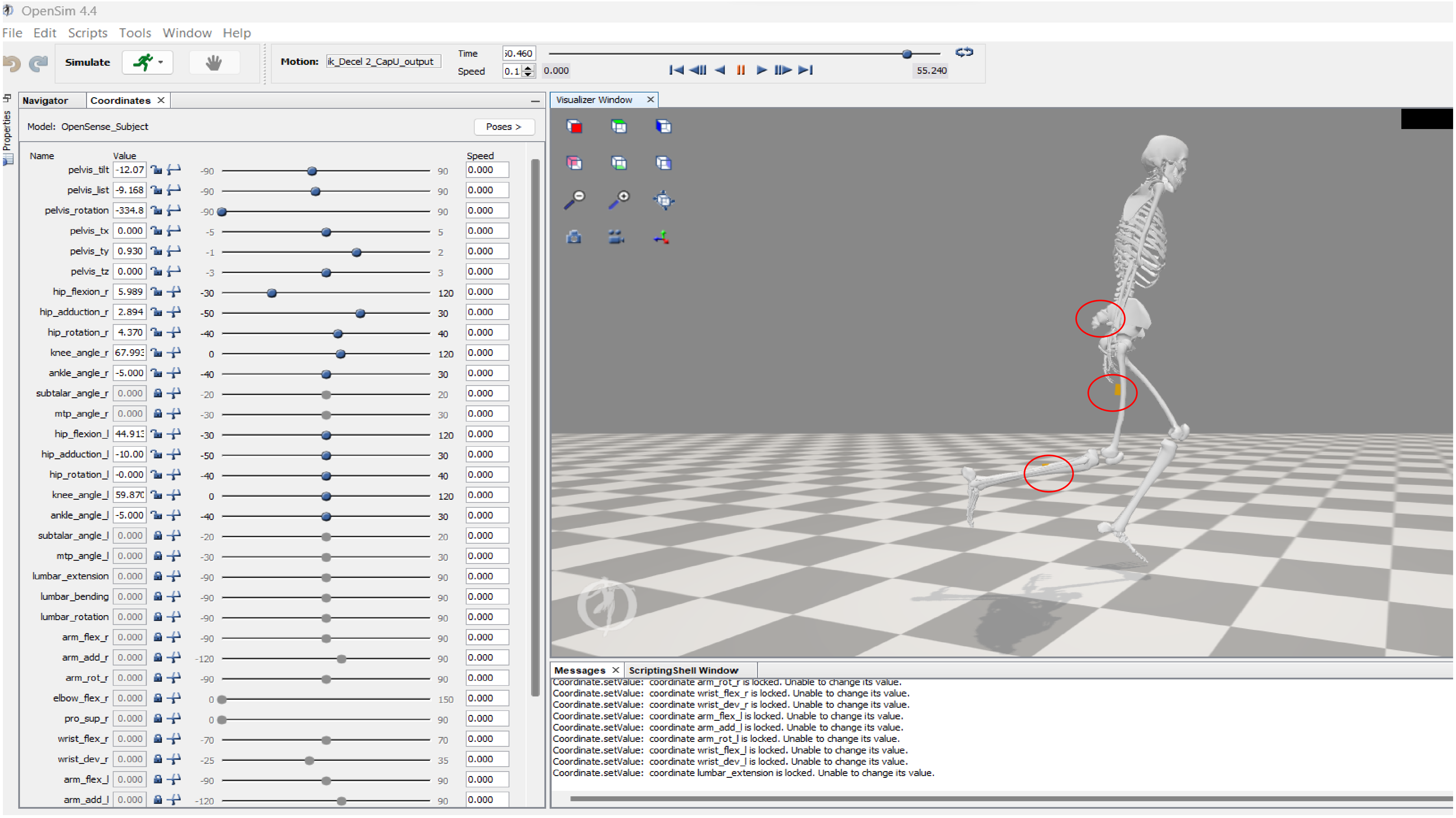
Inertial Measurement Units (IMUs)

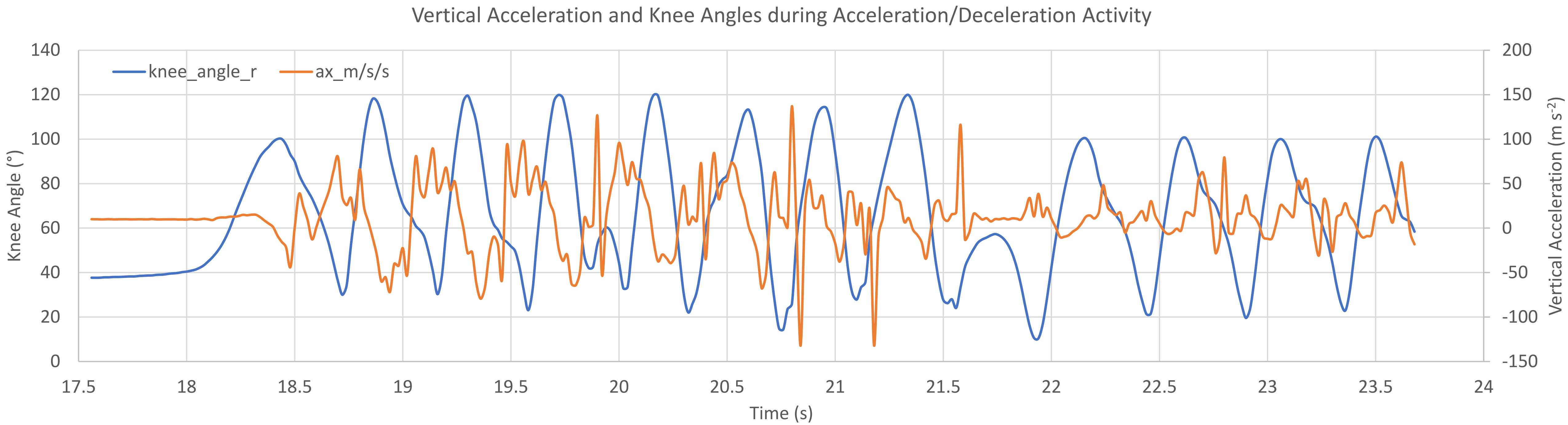
- Two accelerometers (high g and low g), a magnetometer, and a gyroscope
  - Data is fused to determine the orientation of each sensor
- Multiple IMUs can be assigned to body segments of interest
- Aligned data from multiple IMUs imported into modeling software to determine inverse kinematics
  - Peak accelerations
  - Joint angles

OpenSim

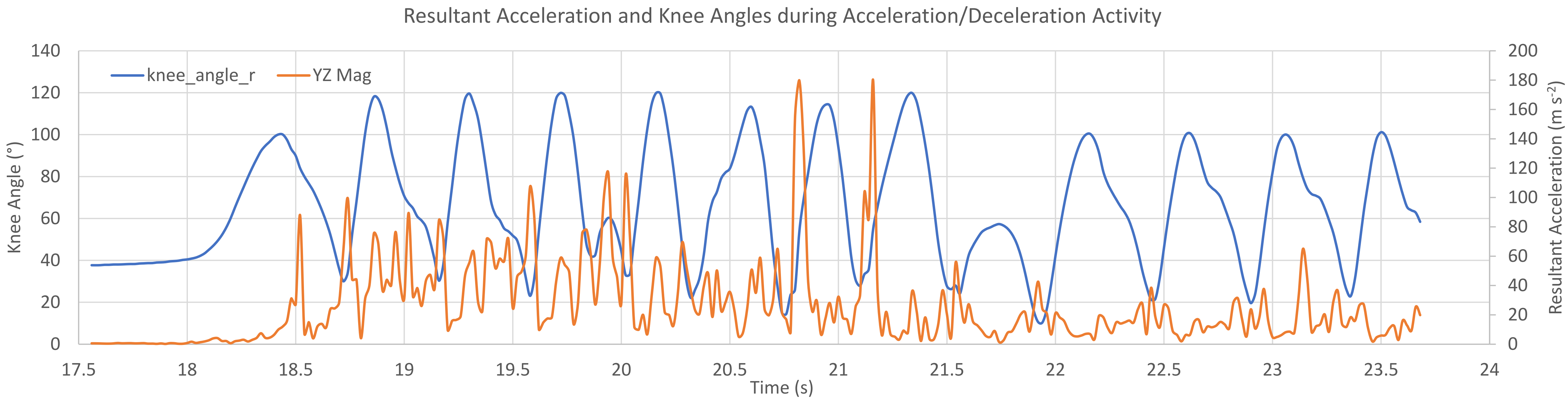


Vicon.com

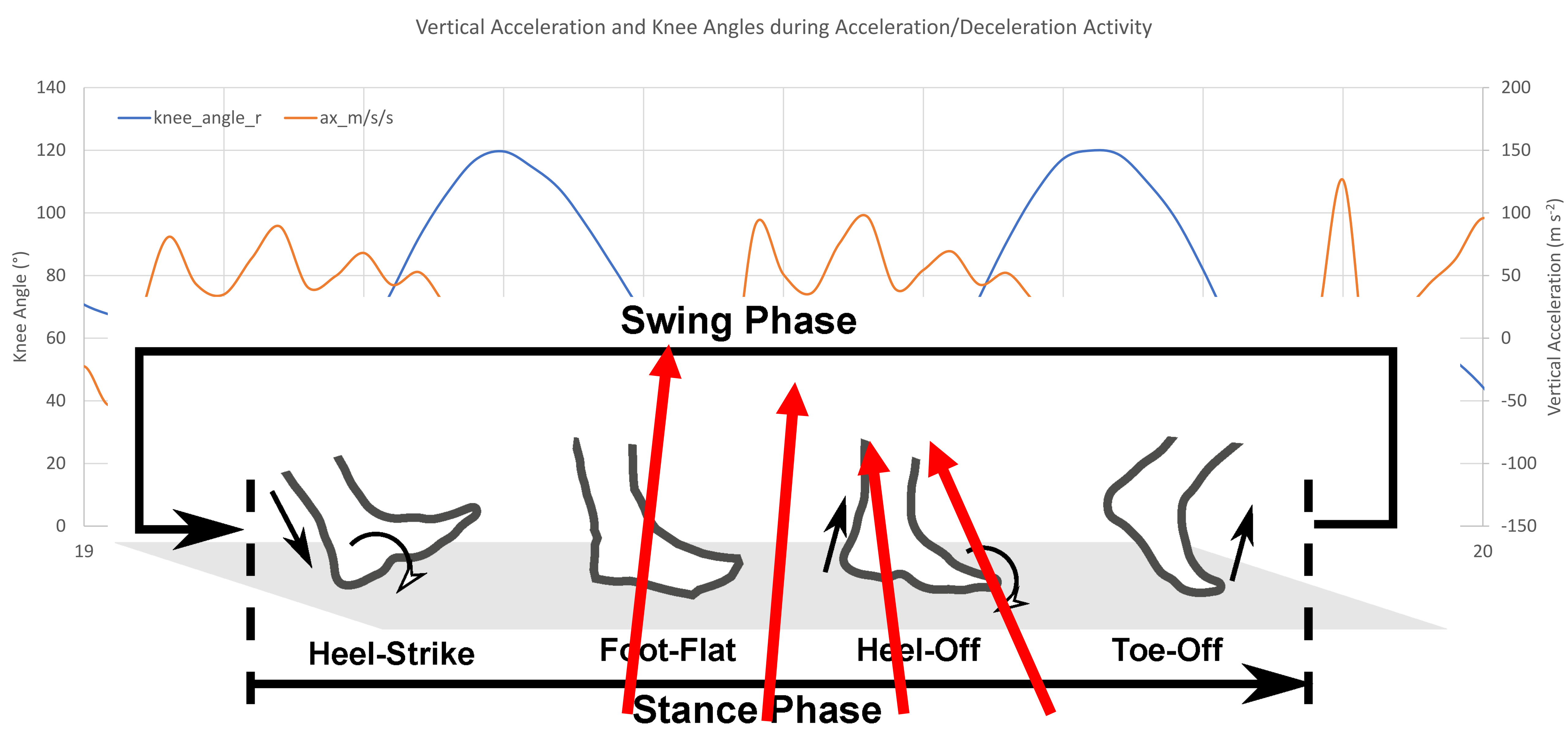

OpenSim 4.4
File Edit Scripts Tools Window Help
Simulate
Motion: ik_Decel 2_CapU_output
Time
Speed 0.1
0.000
55.240
Navigator
Coordinates
Model: OpenSense_Subject
Poses >
Name Value Speed
pelvis_tilt -12.07 -90 90 0.000
pelvis_list -9.168 -90 90 0.000
pelvis_rotation -334.8 -90 90 0.000
pelvis_tx 0.000 -5 5 0.000
pelvis_ty 0.930 -1 2 0.000
pelvis_tz 0.000 -3 3 0.000
hip_flexion_r 5.989 -30 120 0.000
hip_adduction_r 2.894 -50 30 0.000
hip_rotation_r 4.370 -40 40 0.000
knee_angle_r -30 0 120 0.000
ankle_angle_r -5.000 -40 30 0.000
subtalar_angle_r 0.000 -20 20 0.000
mtp_angle_r 0.000 -30 30 0.000
hip_flexion_l -30 120 0.000
hip_adduction_l -10.00 -50 30 0.000
hip_rotation_l -0.000 -40 40 0.000
knee_angle_l 0 120 0.000
ankle_angle_l -5.000 -40 30 0.000
subtalar_angle_l 0.000 -20 20 0.000
mtp_angle_l 0.000 -30 30 0.000
lumbar_extension 0.000 -90 90 0.000
lumbar_bending 0.000 -90 90 0.000
lumbar_rotation 0.000 -90 90 0.000
arm_flex_r 0.000 -90 90 0.000
arm_add_r 0.000 -120 90 0.000
arm_rot_r 0.000 -90 90 0.000
elbow_flex_r 0.000 0 150 0.000
pro_sup_r 0.000 0 90 0.000
wrist_flex_r 0.000 -70 70 0.000
wrist_dev_r 0.000 -25 35 0.000
arm_flex_l 0.000 -90 90 0.000
arm_add_l 0.000 -120 90 0.000
Visualizer Window
Messages
ScriptingShell Window
Coordinate.setValue: coordinate wrist_flex_r is locked. Unable to change its value.
Coordinate.setValue: coordinate wrist_dev_r is locked. Unable to change its value.
Coordinate.setValue: coordinate arm_flex_l is locked. Unable to change its value.
Coordinate.setValue: coordinate arm_add_l is locked. Unable to change its value.
Coordinate.setValue: coordinate arm_rot_l is locked. Unable to change its value.
Coordinate.setValue: coordinate wrist_flex_l is locked. Unable to change its value.
Coordinate.setValue: coordinate wrist_dev_l is locked. Unable to change its value.
Coordinate.setValue: coordinate lumbar_extension is locked. Unable to change its value.



Vertical Acceleration and Knee Angles during Acceleration/Deceleration Activity
knee_angle_r
ax_m/s/s
Knee Angle (°)
Vertical Acceleration (m s-2)
Time (s)



Resultant Acceleration and Knee Angles during Acceleration/Deceleration Activity
knee_angle_r
YZ Mag
Knee Angle (°)
Resultant Acceleration (m s-2)
Time (s)


Vertical Acceleration and Knee Angles during Acceleration/Deceleration Activity
knee_angle_r
ax_m/s/s
Knee Angle (°)
Vertical Acceleration (m s-2)
140
120
100
80
60
40
20
0
200
150
100
50
0
-50
-100
-150
19
20
Swing Phase
Heel-Strike
Foot-Flat
Heel-Off
Toe-Off
Stance Phase

IMU Proof of Concept Study

- Various surfaces
  - ‘Ironcutter’ Hybrid Bermudagrass
  - ‘Champion GQ’ Perennial Ryegrass
  - Large Crabgrass
  - White Clover
  - Synthetic Turf
  - Pavement

Fall/Winter of 2023

IMU Proof of Concept Study

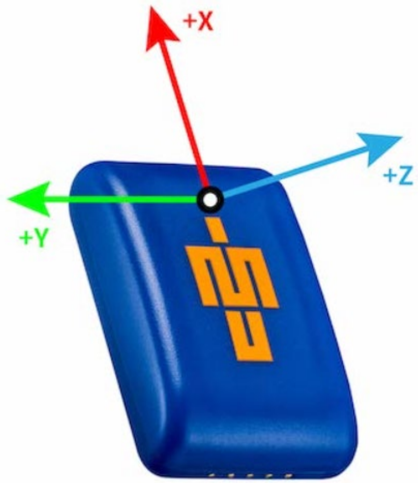
- Participation: 3 males, 5 females
- IMUs were placed on pelvis, thigh, and shank of each participant
- 3 trials of each activity on each surface
- Performance testing matrices were taken before each participant on each surface
  - NDVI
  - VWC
  - Shear strength
  - Surface hardness


Modified Acceleration/
Deceleration
Jump
Landing
Single-Leg
Cut Landing

Data Analysis

- Peak vertical and horizontal force (Fx and Fyz) derived from accelerations measured by the IMUs
  - Force = Mass X Acceleration

- Knee angles were calculated using OpenSense executable of OpenSim



Preliminary Results

'IronCutter' Hybrid Bermudagrass	NDVI	Clegg	VWC (%)	Shear (Nm)
10/2/2023	89	133	16.1	20
10/16/2023	84	97	23.2	19.5
10/23/2023	81	109	21	20
10/26/2023	79	104	23.1	17

Large Crabgrass	NDVI	Clegg	VWC (%)	Shear (Nm)
10/2/2023	80	124	16.2	10.25
10/16/2023	72	83	21.6	7
10/23/2023	75	90	22.8	9
10/26/2023	73	88	25.4	8

'Champion GQ' Perennial Ryegrass	NDVI	Clegg	VWC (%)	Shear (Nm)
12/7/2023	90	96	20.8	18
12/8/2023	87	103	21.9	17
12/16/2023	92	80	24.1	15

White Clover	NDVI	Clegg	VWC (%)	Shear (Nm)
12/7/2023	88	109	19	7
12/8/2023	85	115	20.2	8
12/16/2023	86	99	23	5

Synthetic Field	Infill Depth (mm)	Clegg
11/29/2023	22	143
11/30/2023	22	143
12/16/2023	27	147

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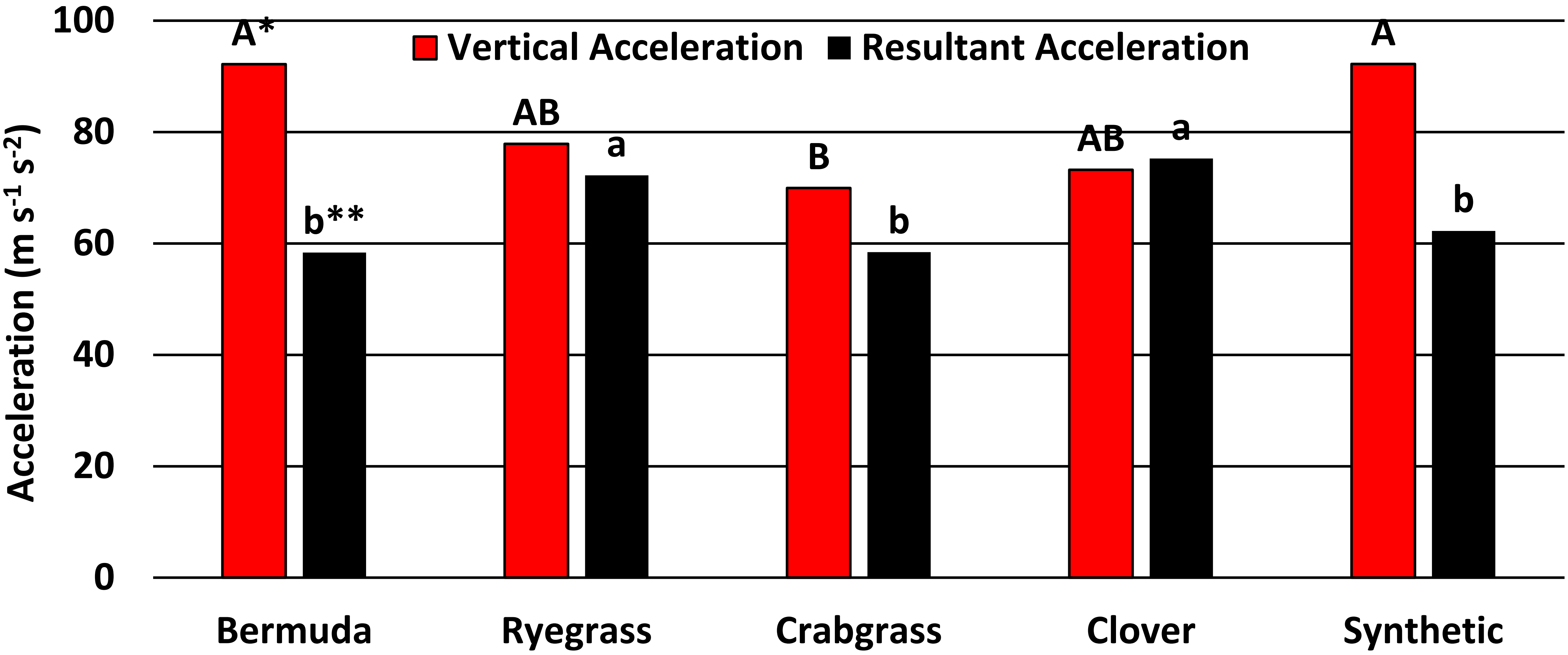
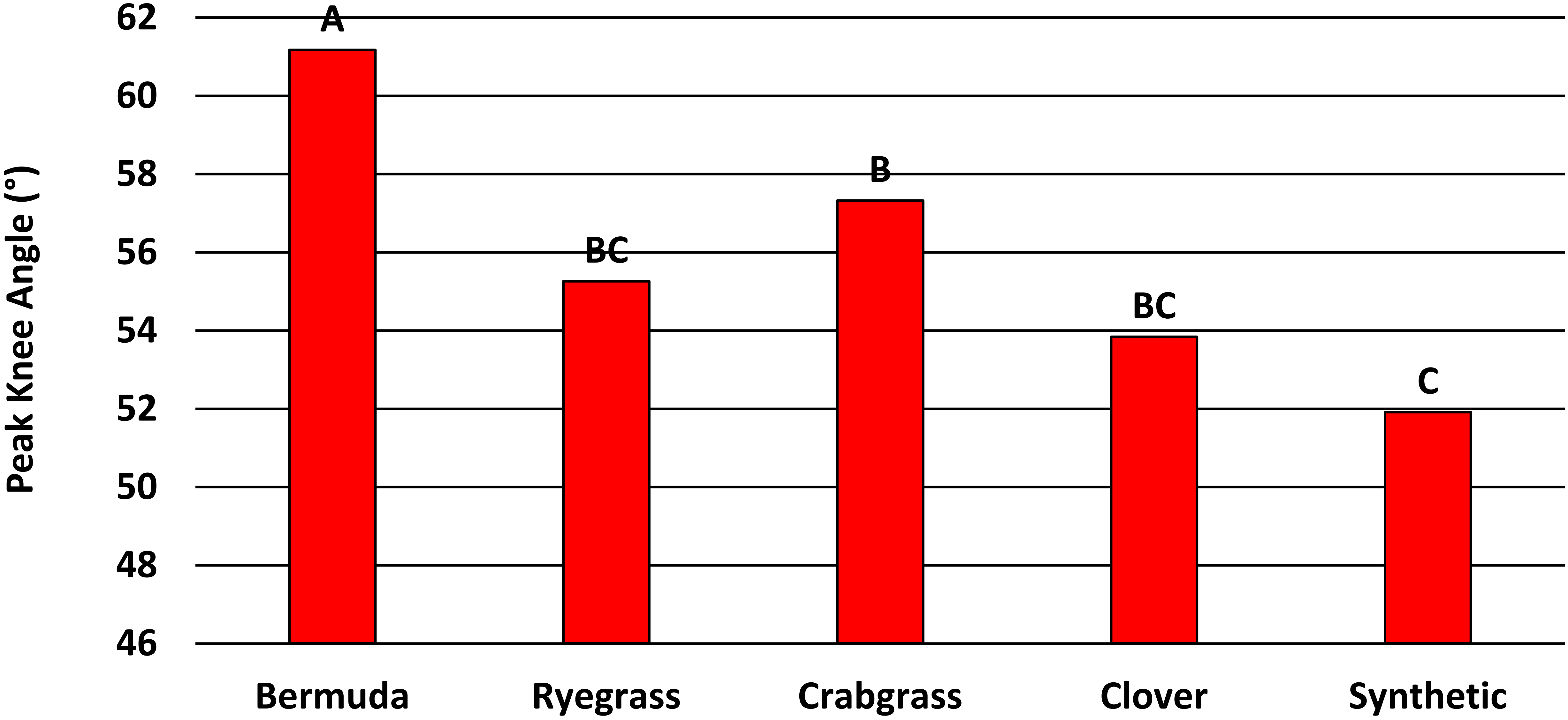
Single-Leg Cut Landing Peak Tibial Vertical and Horizontal Acceleration



*Vertical $LSD_{0.05}$ = 19 m s^{-1} s^{-2}

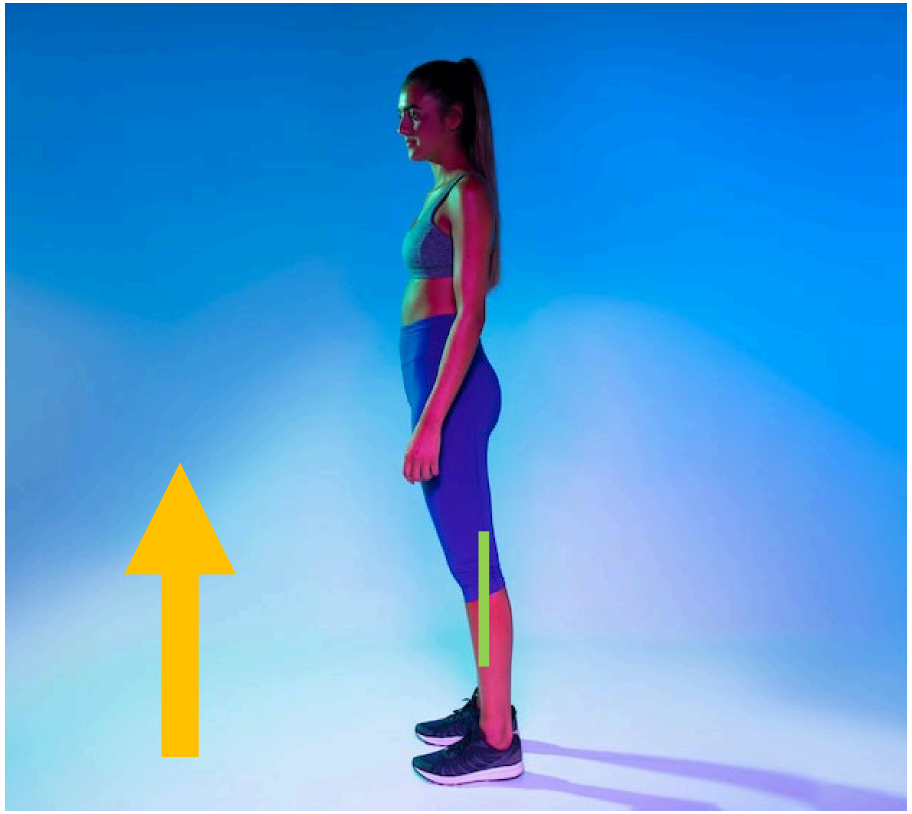
**Resultant $LSD_{0.05}$ = 9.91 m s^{-1} s^{-2}

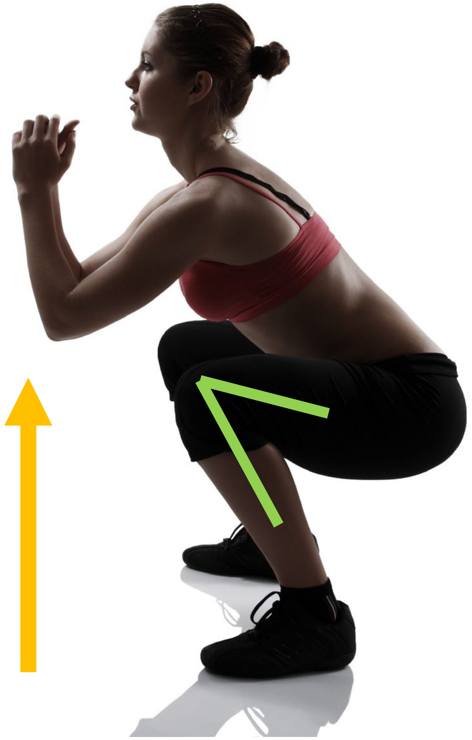
Single-Leg Cut Landing Peak Knee Angle



Injury Prevention

High Returned Force Low





Low Knee Flexion High

Discussion

- Reduced knee flexion angles when landing increases injury risk
- Reduced knee flexion angle may not be directly related to surface hardness
- Other factors that influence knee flexion on landing:
  - Subsurface and infill material
  - Growth habit (stolons/rhizomes vs bunch type)
  - Etc.

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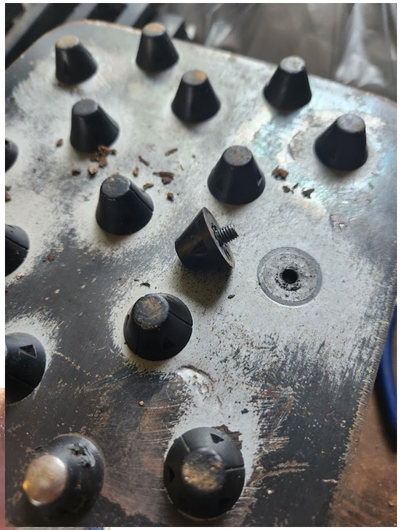
12/16/2023	27	147

Future Research

Biophysical Effects and Ground Force of the Baldree Traffic Simulator

A.R. Kowalewski,* B.M. Schwartz, A.L. Grimshaw, D.G. Sullivan, J.B. Peake, T.O. Green, J.N. Rogers, III, L.J. Kaiser, and H.M. Clayton.

Wear and Traffic Simulator



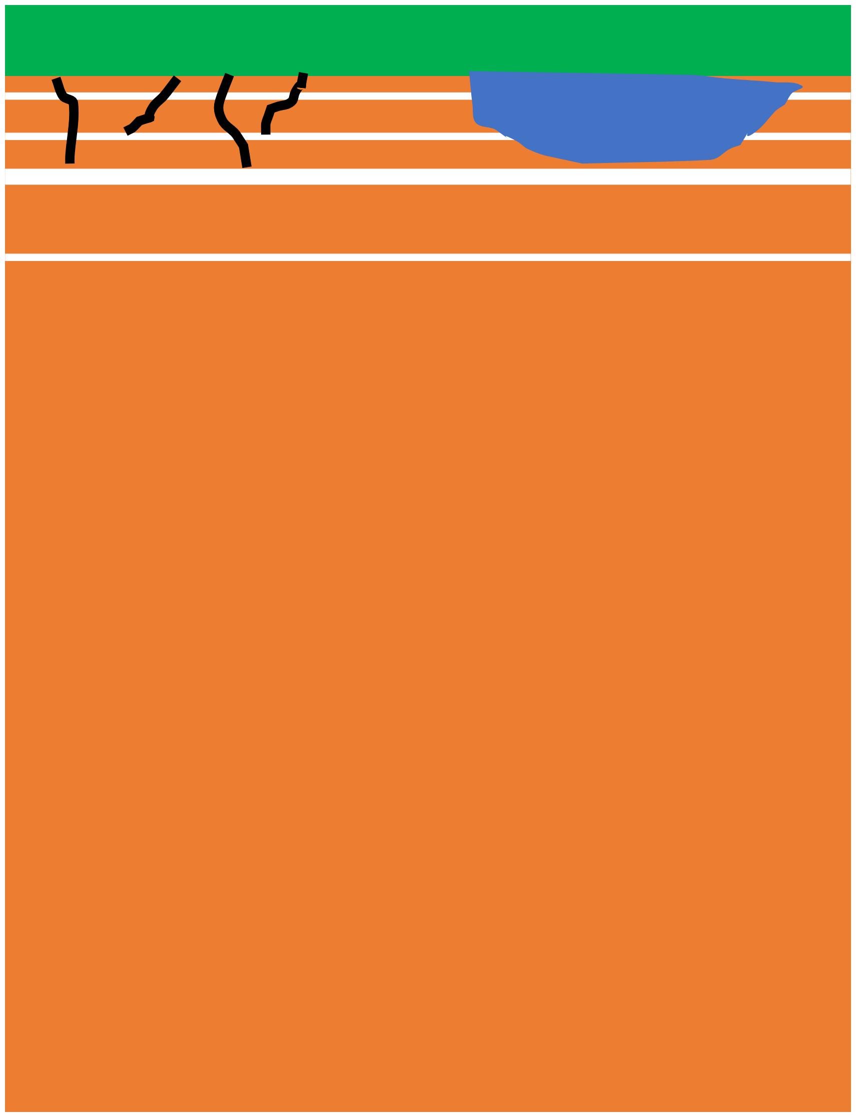

Athlete Running Lanes
Natural Grass
Synthetic Turf
Overseeded
Weed Pressure
Trafficked Strip

Athletic Field Painting

Audrey Young

Paint Layering

- Caused over time in response to heavy paint applications
- Layers of paint may cause several negative interactions
  - Disrupt turfgrass rooting and reduce shear strength
  - Decrease water infiltration and rewetting potential




Painted Surfaces
Non-painted Area


Fraise Mowed Area


Athlete Running Lanes

Natural
Grass

Synthetic
Turf

Natural
Grass

Synthetic
Turf

Painted
Area

Questions?

E-mail:
gmhenry@uga.edu
ebegitsc@uga.edu

SFMA WHERE THE GAME BEGINS