Associations of Inertial Measurements with Pre-Season Injury Occurrences among College Football Players

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Disclosure

- We have nothing to disclose

Introduction

- Workload association with injury risk remains poorly understood[1]
  - Tissue failure when load exceeds tolerance (chronic or acute loading)[2]
  - Tissue adaptations to loading can enhance tolerance (decreased risk)[3]

- High average load = susceptibility (fatigue)[3] OR resilience (fitness)[4]
  - High load increases risk in collision sports (particularly in pre-season)[5,6]
  - Exposure to collisions essential to prepare for competition demands[7]

- Wearable inertial measurement unit (IMU) data may or may not provide useful metrics for assessment of injury risk

Purpose Statement

- To analyze data collected during college football practice sessions from wearable inertial measurement units (IMUs) across two successive seasons to assess a possible relationship between training load or monotony to occurrences of core or lower extremity injury (CLEI) across pre-season practice sessions and regular season games.

Methods

IRB #23-052

- 102 Male NCAA Division -1 FCS Football Players
  - 2023: 57 Athletes; Age Range: 18-24; Mass: 102.3 Kg; Height: 184.5 cm
  - 2024: 45 Athletes; Age Range: 18-25; Mass: 98.0 Kg; Height: 184.2 cm
    - 42% (19/45) participated in both 2023 and 2024
    - 16% (3/19) of 2-year players injured during pre-season period of both years

- IMU Device: Catapult One (Catapult Sports, Chicago, IL)
  - Measurement validity and reliability previously established[8]
  - Worn in vest or shoulder pad pouch by players expected to have high-volume game participation
  - IMU data aggregation: PlayerTek Software (Catapult Sports USA, Chicago, IL)

- Surveillance Period:
  - 2023: Pre-season (24 days) and regular season (114 days)
  - 2024: Pre-season (23 days) and regular season (113 days)

- Injury Documentation (Sportsware, CSMI, Stoughton, MA)
  - Core or lower extremity injury (CLEI): Any sprain or strain that interrupted participation and was treated

Calculation of “Player Load”

IRB #23-052

- Inertial Measurement Unit 100-Hz sampling rate[9]
  - Player Load (PL): Instantaneous rate of acceleration/deceleration
    - aca: acceleration anterior-posterior
    - act: acceleration transverse
    - acv: acceleration vertical

$$\text{Player load} = \sqrt{\left((aca_{t=i+1} - aca_{t=1})^2 + (act_{t=i+1} - act_{t=1})^2 + (acv_{t=i+1} - acv_{t=1})^2\right)} \Big/ 100$$

Statistical Analyses

- Pre-season surveillance period (including 2 practice scrimmages)

  2023: 16 recording sessions: 24 days
  Median=14; Range: 4-16
  82% (752/912) acquired

  2024: 17 recording sessions: 23 days
  Median=12; Range: 4-17
  70% (532/765) acquired

- Player Load and Monotony (Avg Player Load / Across-Sessions Std Dev)
  - Uninjured (all available pre-season recordings); Injured (minimum of 4 pre-injury recordings)
    - Potential cause must precede injury to infer a contributory role

- Potential confounding factors assessed:
  - Position Category; Starter Status; Lifetime Concussion History; CLEI History (prior 12 mo)
    - Skilled Position: QB, RB, WR, TE, DB
    - Interior Position: OL, DL, DE, LB

- Receiver operating characteristic, chi-square, and Cox regression analyses

Classification of Injury vs. No Injury 2023 – 2024 Comparison

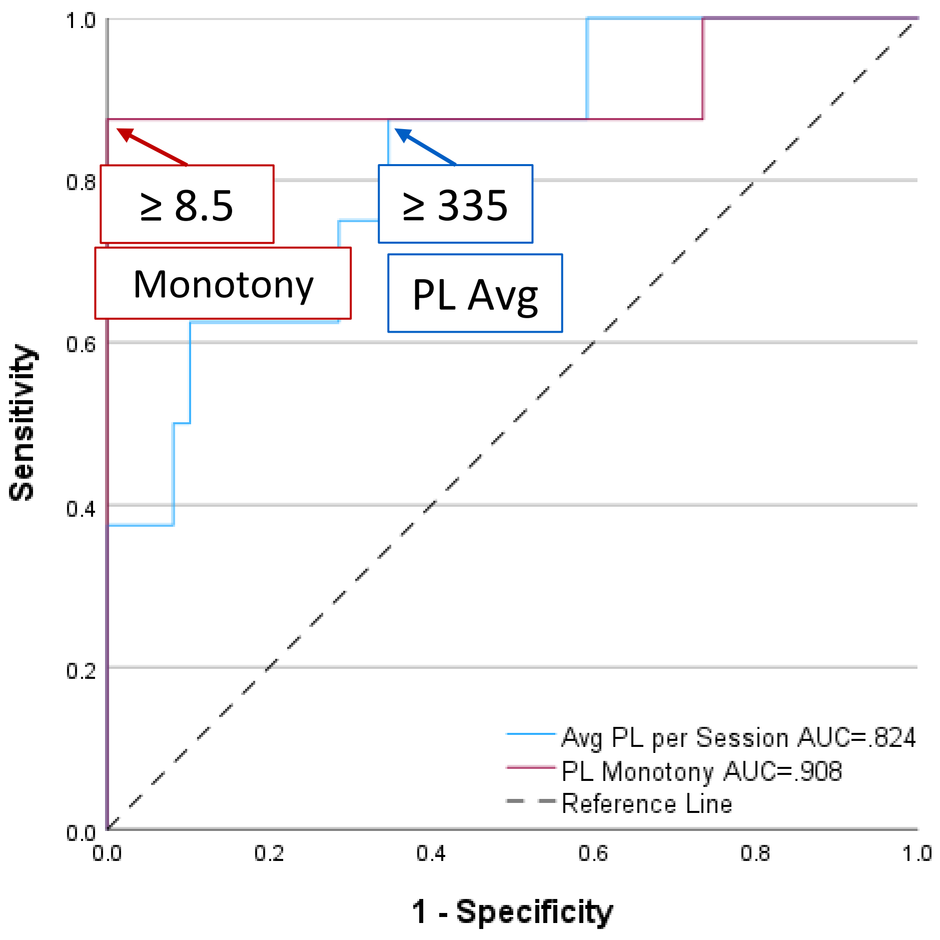
	Pre-Season Core and Lower Extremity Injuries*						
Injury Category	**Abdomen**	**Hip/Groin**	**Thigh**	**Knee**	**Lower Leg**	**Ankle**	**Foot**
2023	0	3	0	3	2	0	0
2024	1	0	0	3	0	2	0

	Pre-Season + Regular Season Core and Lower Extremity Injuries*						
Injury Category	**Abdomen**	**Hip/Groin**	**Thigh**	**Knee**	**Lower Leg**	**Ankle**	**Foot**
2023	0	2	3	9	4	7	3
2024	1	2	0	6	0	8	0

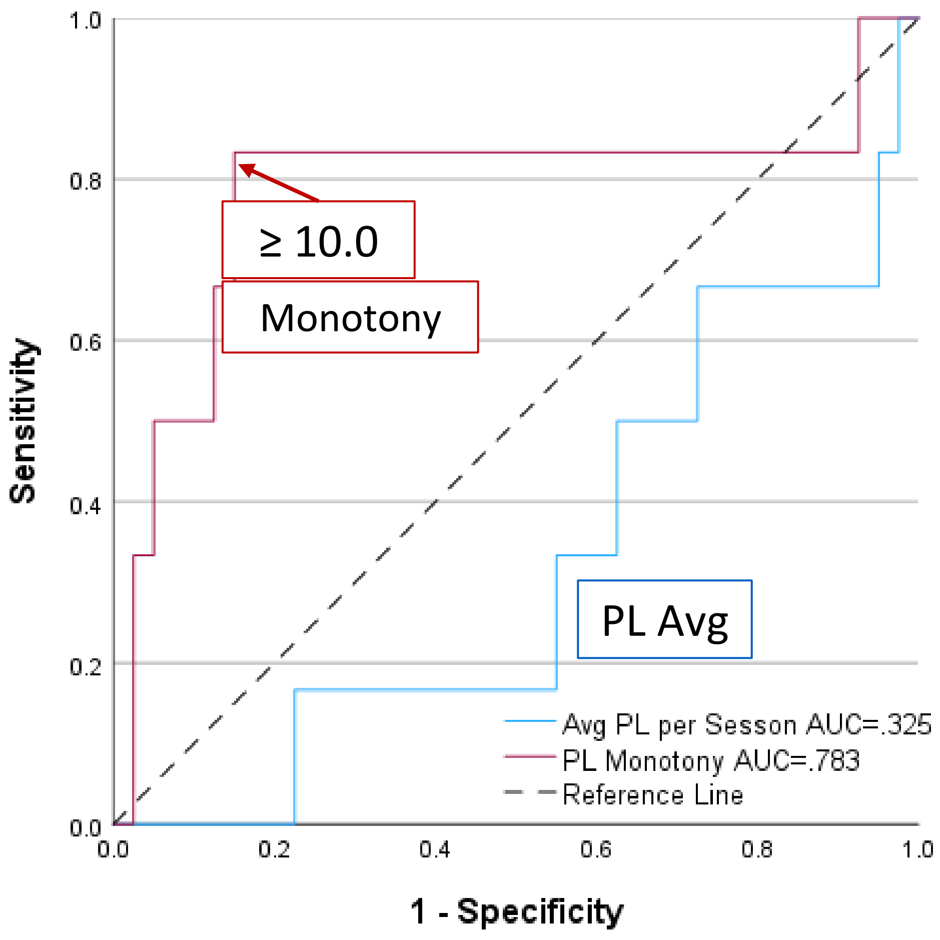
* Number of injured players (at least 1 injury)

Avg PL and Monotony as Pre-Season Injury Predictors

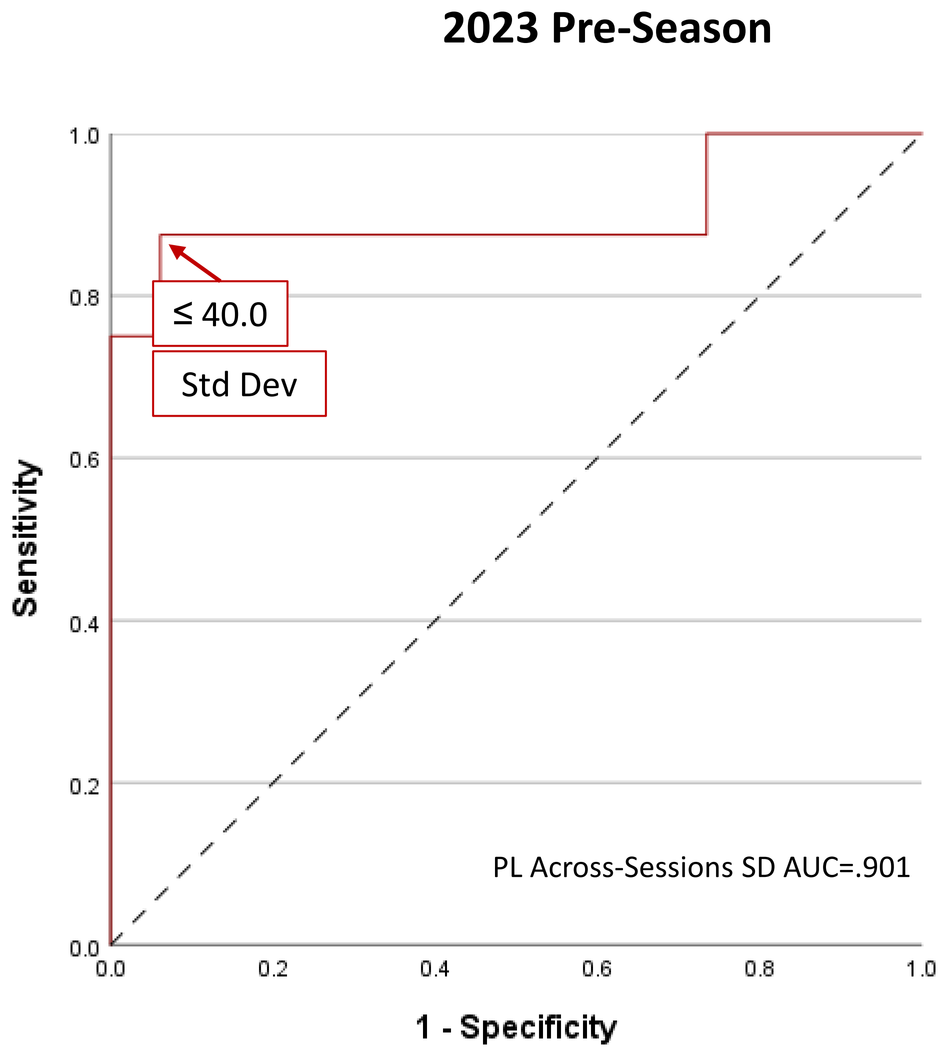
2023 Pre-Season

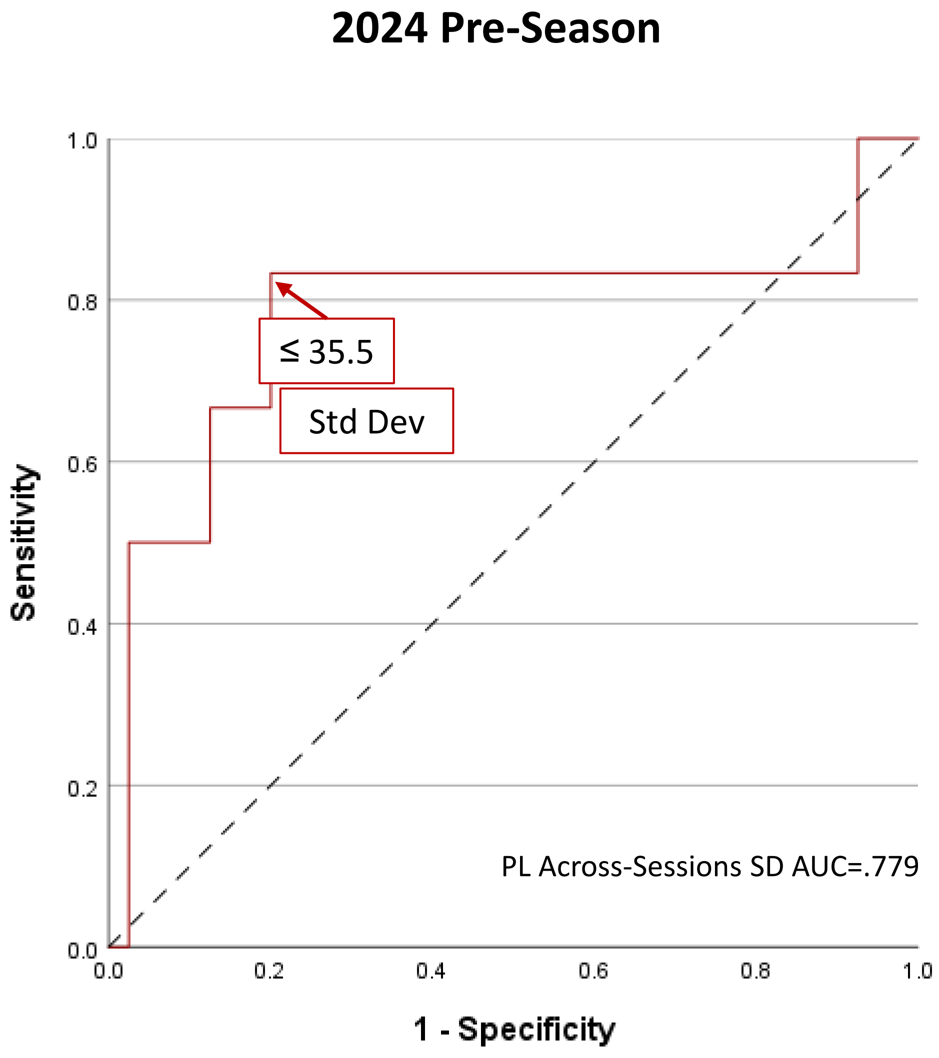


2024 Pre-Season

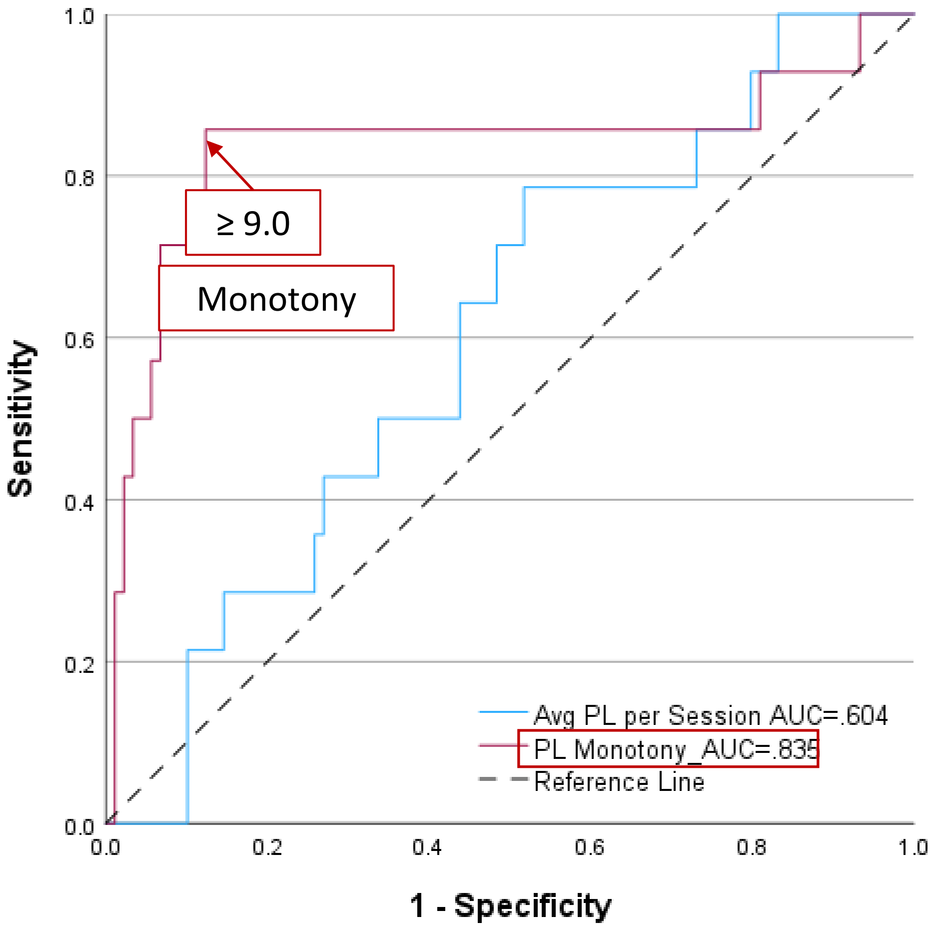


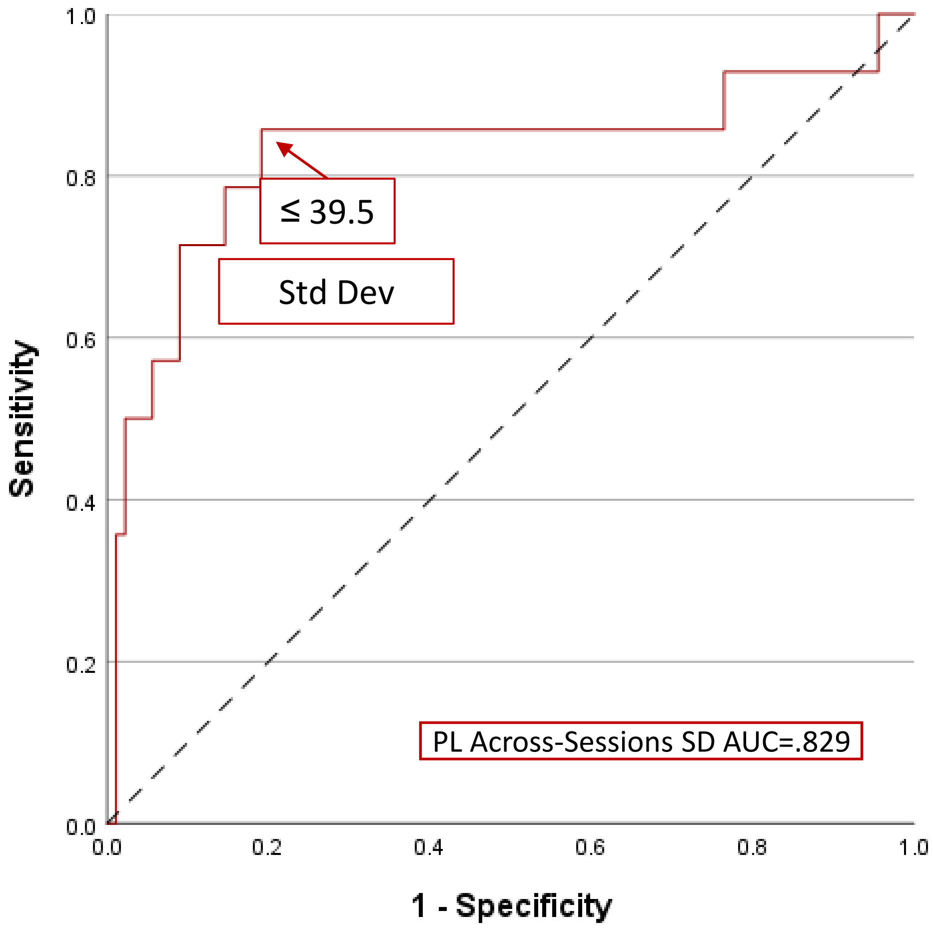
Across-Sessions Std Dev as Pre-Season Injury Predictor





Combined 2023 + 2024 Pre-Season Data





Combined 2023 + 2024 Data: Pre-Season

		PreS CLEI		
		Yes	No	Prev.
Participated Both Years	Yes	6	32	16%
	No	8	56	13%
	Total	14	88	

Sensitivity: 43% Specificity: 88%

OR = 1.31 (95% CI: 0.42, 4.12)

		PreS CLEI		
		Yes	No	Prev.
Position Category - Interior	Yes	10	30	25%
	No	4	58	7%
	Total	14	88	

Sensitivity: 71% Specificity: 66%

OR = 4.83 (95% CI: 1.40, 16.71)

		PreS CLEI		
		Yes	No	Prev.
Starter Status	Yes	8	47	15%
	No	6	41	13%
	Total	14	88	

Sensitivity: 57% Specificity: 47%

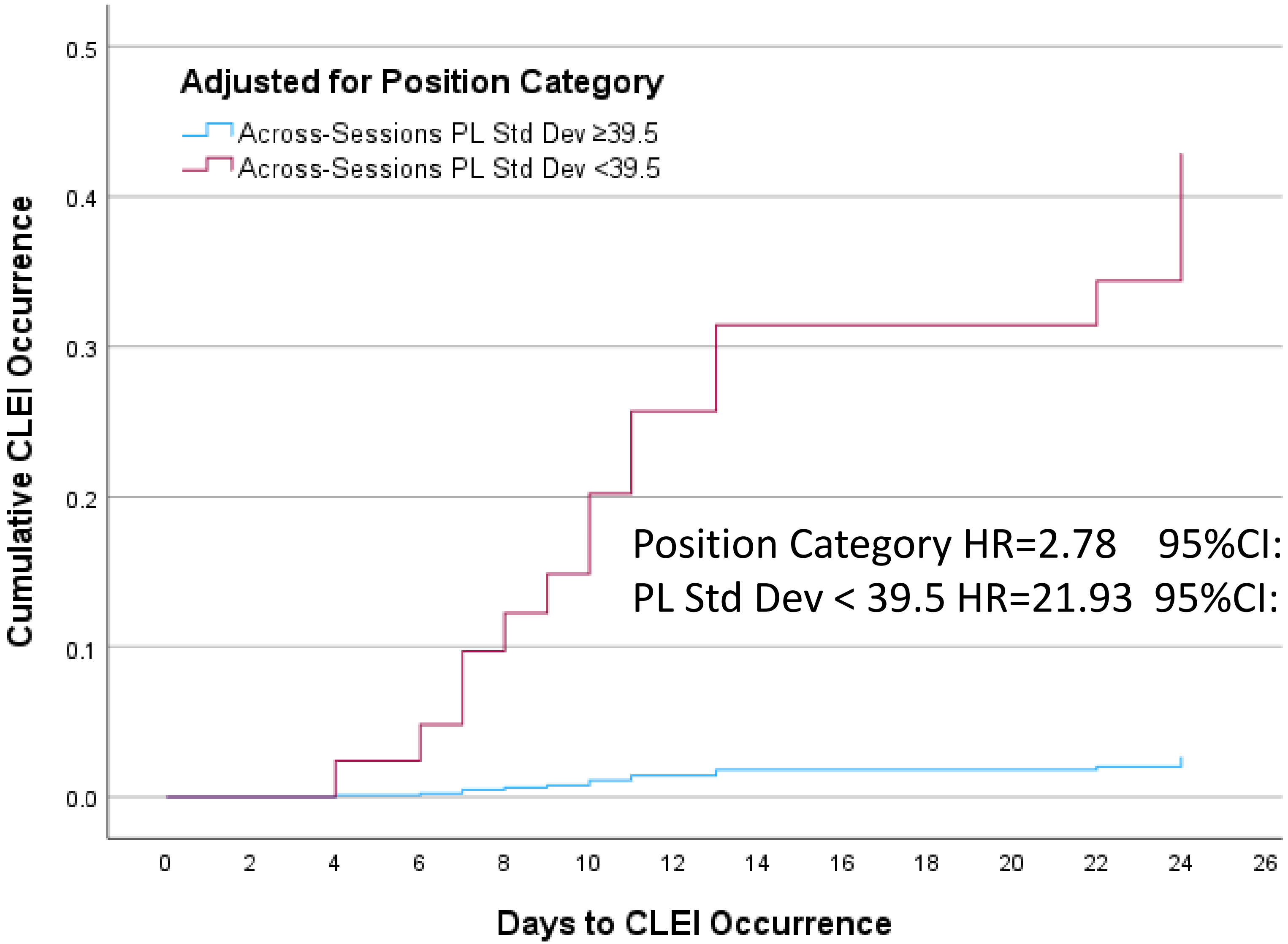
OR = 1.16 (95% CI: 0.37, 3.63)

		PreS CLEI		
		Yes	No	Prev.
Across-Sessions PL Std Dev	< 39.5	12	16	43%
	≥ 39.5	2	72	3%
	Total	14	88	

Sensitivity: 86% Specificity: 82%

OR = 27.00 (95% CI: 5.50, 132.66)

Combined 2023 + 2024 Pre-Season Data
Cox Regression Time-to-Event Analysis



Position Category HR=2.78 95%CI: 1.63, 4.72

PL Std Dev < 39.5 HR=21.93 95%CI: 4.78, 100.62

Combined 2023 + 2024 Pre-Season + Regular Season Data

		Full Season CLEI		
		Yes	No	Prev.
Participated Both Years	Yes	16	22	42%
	No	29	35	45%
	Total	45	57	

Sensitivity: 36% Specificity: 61%

OR = 0.88 (95% CI: 0.39, 1.97)

		Full Season CLEI		
		Yes	No	Prev.
Position Category - Interior	Yes	23	17	58%
	No	22	40	36%
	Total	45	57	

Sensitivity: 51% Specificity: 70%

OR = 2.46 (95% CI: 1.09, 5.56)

		Full Season CLEI		
		Yes	No	Prev.
Starter Status	Yes	31	24	56%
	No	14	33	30%
	Total	45	57	

Sensitivity: 69% Specificity: 58%

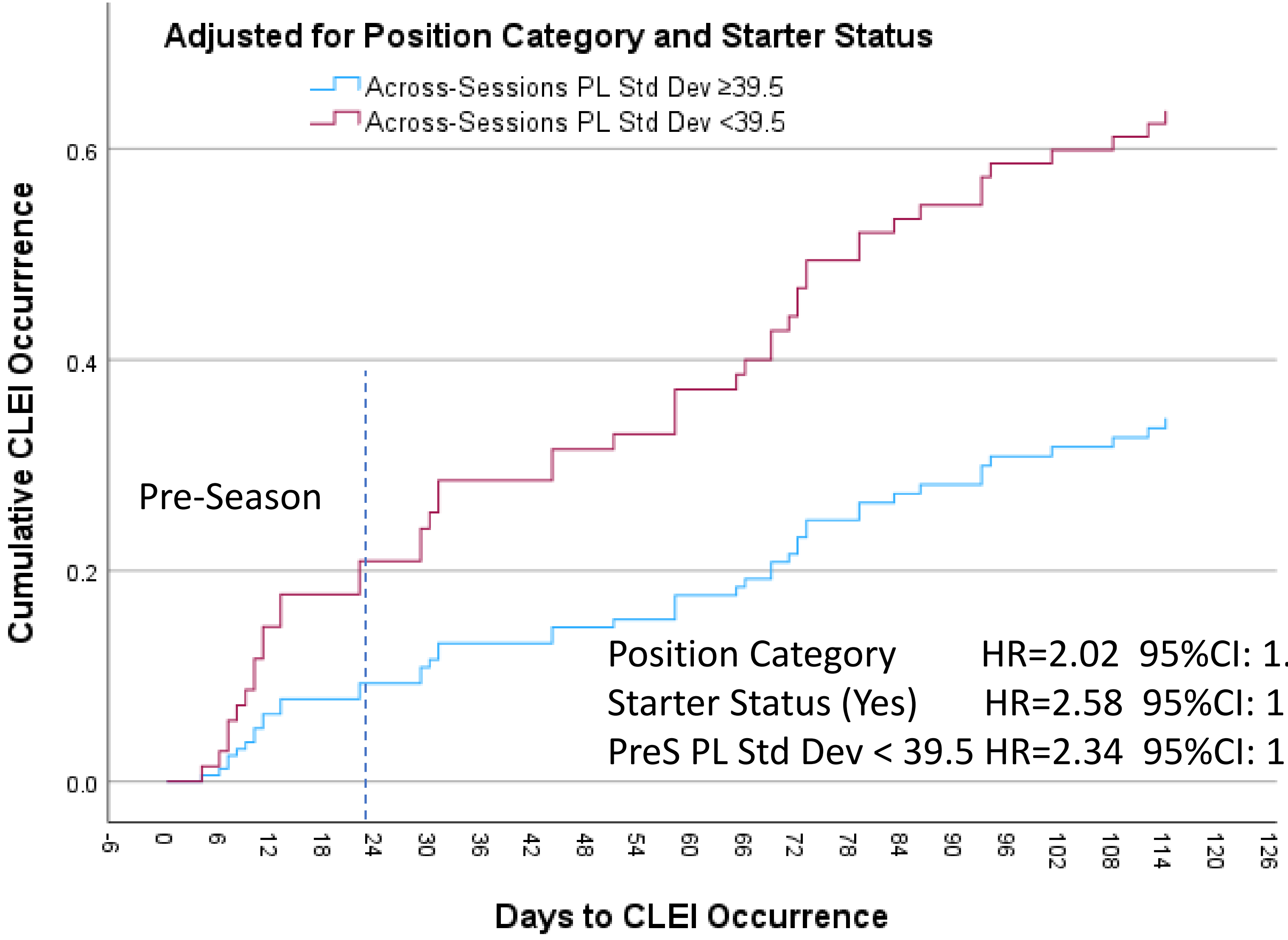
OR = 3.05 (95% CI: 1.34, 6.92)

		Full Season CLEI		
		Yes	No	Prev.
Pre-S Across-Sessions PL Std Dev	< 39.5	17	11	61%
	≥ 39.5	28	46	38%
	Total	45	57	

Sensitivity: 38% Specificity: 81%

OR = 2.54 (95% CI: 1.04, 6.20)

Combined 2023 + 2024 Pre-Season + Regular Season Data
Cox Regression Time-to-Event Analysis



Position Category	HR=2.02	95%CI: 1.12, 3.64
Starter Status (Yes)	HR=2.58	95%CI: 1.35, 4.92
PreS PL Std Dev < 39.5	HR=2.34	95%CI: 1.28, 4.29

Clinical Relevance

- High Player Load may indicate good adaptability/resilience[2]
  - No evidence supports reduction of injury risk through load reduction

- Pre-season exposure to collisions necessary to prepare for season[6,7]
  - Effective responses to task constraints and attenuation of impacts[10]

Clinical Relevance

- No compelling evidence supports Player Load (PL) or Acute:Chronic Workload Ratio (ACWR) as valid indicators of injury susceptibility[4]
- Monotony (Avg PL / Std Dev of PL) did not exhibit a substantially stronger association with injury compared to Std Dev of PL alone

Clinical Relevance

- Excessively rigid and unchanging patterns (low variability) may concentrate loads and produce microstructural tissue damage

- Multiple differing responses to a given scenario may produce equivalent performance results (kinematic/kinetic variability)

Clinical Relevance

- Movement/load variability may reflect complex system flexibility[11]
- Std Dev of PL (across-sessions variability) might be increased by perceptual response training
  - Brain processing efficiency supporting a broad repertoire of responses[12]

References

1. Kalkhoven JT, et al. Training load and injury: causal pathways and future directions. *Sports Med*. 2021;51:1137-1150.
2. Kalkhoven JT, et al. A conceptual model and detailed framework for stress-related, strain-related, and overuse athletic injury. *J Sci Med Sport*. 2020;23(8):726-734.
3. Nordin AD, Dufek JS. Reviewing the variability-overuse injury hypothesis: Does movement variability relate to landing injuries?. *Res Q Exerc Sport*. 2019;90(2):190-205.
4. Impellizzeri FM, et al Acute:chronic workload ratio: conceptual issues and fundamental pitfalls. *Int J Sports Physiol Perform*. 2020;15(6):907-913.
5. Gabbett TJ, Domrow N. Relationships between training load, injury, and fitness in sub-elite collision sport athletes. *J Sports Sci*. 2007;25(13):1507-1519.
6. Sampson JA, et al. Injury risk-workload associations in NCAA American college football. *J Sci Med Sport*. 2018;21(12):1215-1220.
7. Wellman AD, et al. Quantification of accelerometer derived impacts associated with competitive games in National Collegiate Athletic Association Division I college football players. *J Strength Cond Res*. 2017;31(2):330-338.
8. Scott MT, et al. The validity and reliability of global positioning systems in team sport: a brief review. *J Strength Cond Res*. 2016;30(5):1470-1490.
9. Casamichana D, et al. Relationship between indicators of training load in soccer players. *J Strength Cond Res*. 2013;27(2):369-374.
10. Bartlett R, et al. Is movement variability important for sports biomechanists?. *Sports Biomech*. 2007;6(2):224-243.
11. Sternad D. It's not (only) the mean that matters: variability, noise and exploration in skill learning. *Curr Opin Behav Sci*. 2018;20:183-195.
12. Hadders-Algra M. Variation and variability: key words in human motor development. *Phys Ther*. 2010;90(12):1823-1837.