Effects of Perceptual Response Training on Injury Incidence among Women's Collegiate Soccer Players

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Introduction

- Perceptual decisions influence injury risk and sport performance[1]
  - Perception = Detection + discrimination of environmental stimuli
  - Perceptions linked to muscle activations through decision processes
- Optimal sport performance depends on fast + accurate decisions
  - Rapid deceleration/acceleration provides competitive advantage[2]
  - Avoidance of collisions or resistance to impending impacts may reduce risk for concussion + musculoskeletal injury[3]

Introduction

- Virtual reality (VR) precisely measures visual stimulus responses[4]
  - Permits analysis of speed-accuracy tradeoff and across-trial variability
  - Perceptual response training may enhance decision making
- Estimation of injury risk is essential to guide injury prevention[5]
  - Existing tests insufficiently sensitive to detect subtle impairments
  - History of concussion is known to have long-lasting adverse effects

Purpose

To assess the possible beneficial effect of immersive VR perceptual response training on decision-related metrics and injury incidence among college women's soccer players.

Participants and Procedures

IRB #23-052

- NCAA D-I soccer players (n=26)
  - Inclusion: On team roster for 2024 season
  - Exclusion: Any injury-related impairment
    - Age: 19.5 ±1.3 years
    - Height: 168.0 cm ±5.5 cm
    - Mass: 63.6 kg ±14.9 kg

- VR tests
  - Baseline
    - Training group (early arrival): n=10
  - Pre-participation
    - Training group (after 10 training sessions)
    - No training (late arrival): n=16
  - Post-season follow-up

* Missing data imputation with group mean value (2 cases)

- Global Well-Being Index
  - Self-reported history of concussion

- Injury surveillance
  - First practice session to final game (14 wks)
  - Any core or lower extremity sprain/strain
    - Acute or overuse musculoskeletal injury

VR Perceptual Response Training

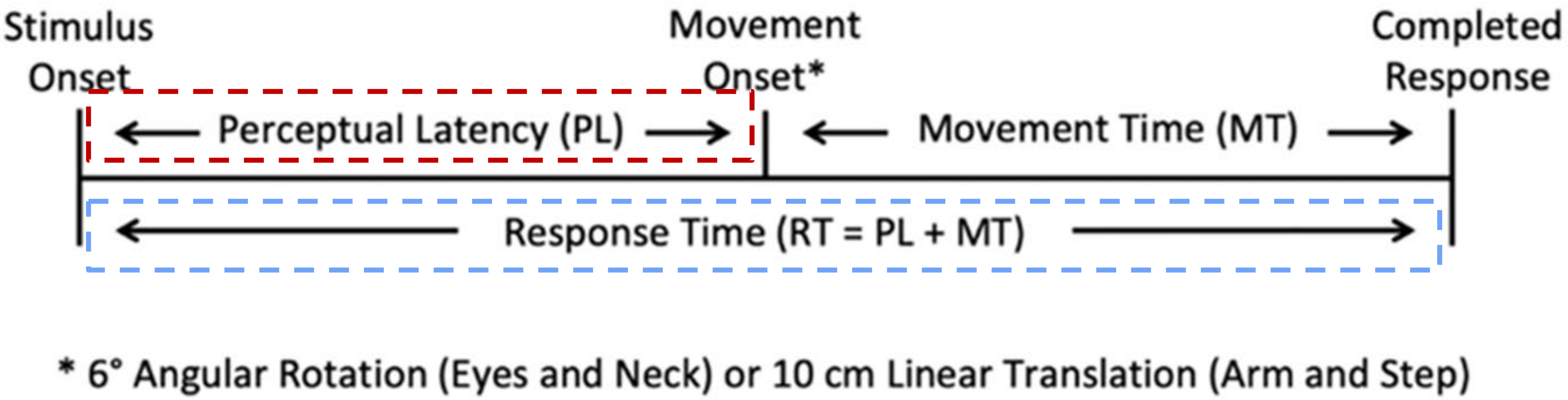
- 40 trials per session
  - Stimulus-response instructions:
    - Move same direction as filled circles
    - Move opposite direction of rings

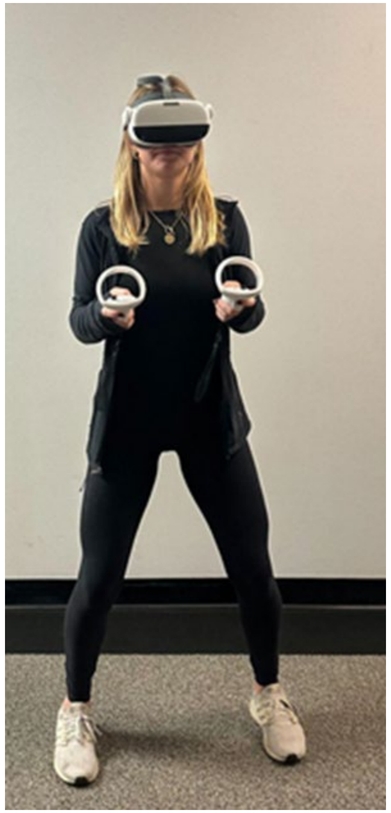
- Progression
  - Level 1: 1 circle or ring
  - Level 2: 3 circles/rings; target in middle
  - Level 3: 3 circles/rings; target flashing
  - Level 4: 3 circles/rings; faster motion

Level 1

Level 2

Operational Definitions
(Elapsed Time Segments)





Key Metrics:

Rate Correct per Second = **<u># Correct / Sum of Perceptual Latency Values</u>** for 40 Trials

Intra-Individual Variability = **<u>Standard Deviation of Perceptual Latency Values</u>** across 40 Trials

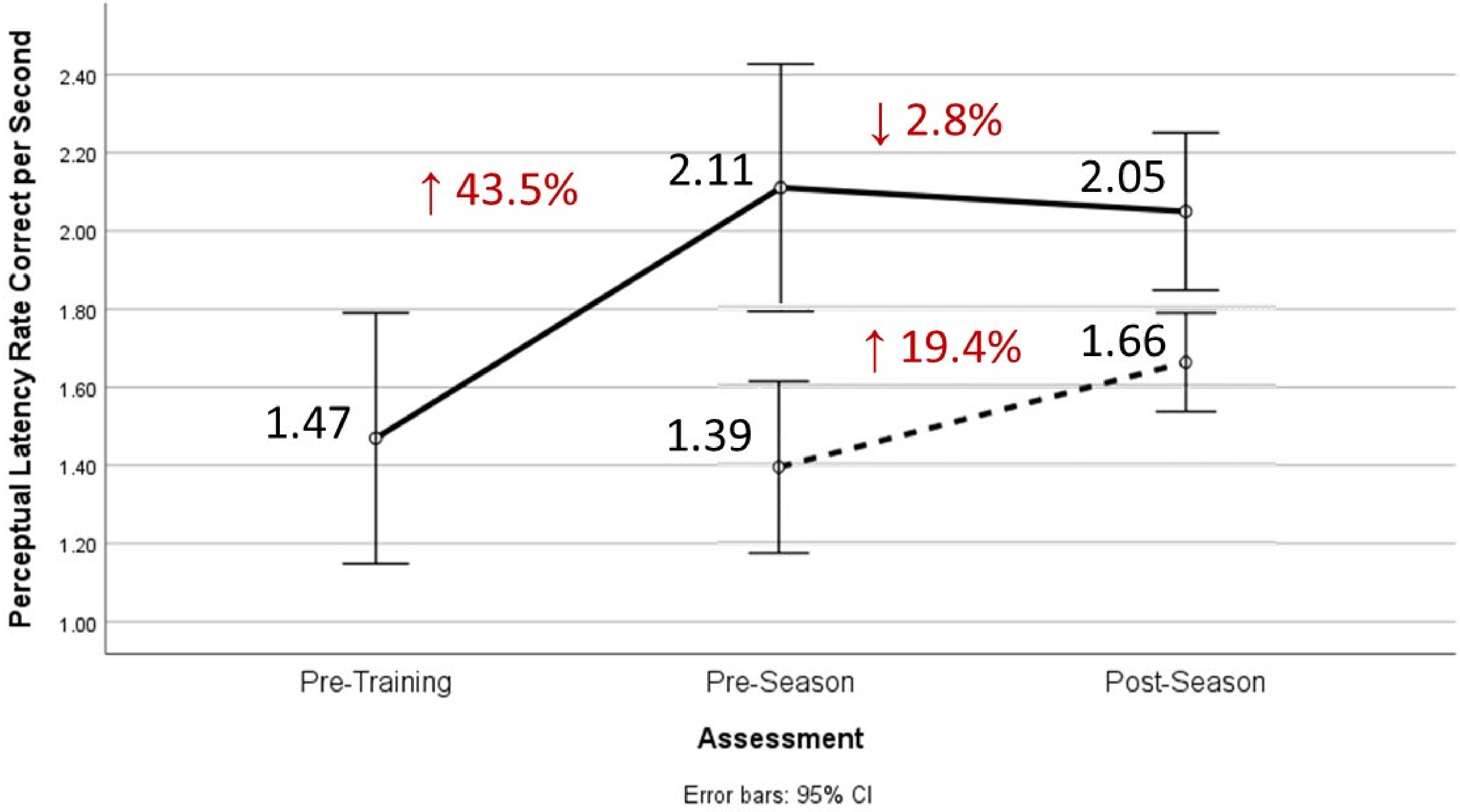
*** Perceptual Latency metrics for <u>Neck</u> most sensitive to change and had strongest associations with injury**

Statistical Analyses and Results

- Paired t-tests for Training Group Pre- to Post-training comparisons
  - Neck Rate Correct per Second – Perceptual Latency
    - P=.012; d=1.00
  - Neck Perceptual Latency Variability
    - P=.002; d=1.34
  - Neck Behavioral Efficiency Index (RCS-PL / PL Variability)
    - P<.001; d=1.75
- Repeated measures ANOVA for Group Pre-participation and Follow-up comparisons
  - Neck Rate Correct per Second – Perceptual Latency
    - Group Main Effect P<.001; η_p^2=.510
  - Neck Perceptual Latency Variability
    - Group Main Effect P<.001; η_p^2=.503
  - Neck Behavioral Efficiency Index (RCS-PL / PL Variability)
    - Group X Session Interaction P=.017; ; η_p^2=.216, Group Main Effect P<.001; η_p^2=.717
- Kaplan-Meier time-to-event analysis for ROC-derived cut point for Neck BEI
    - Mantel-Cox Log Rank P = .059

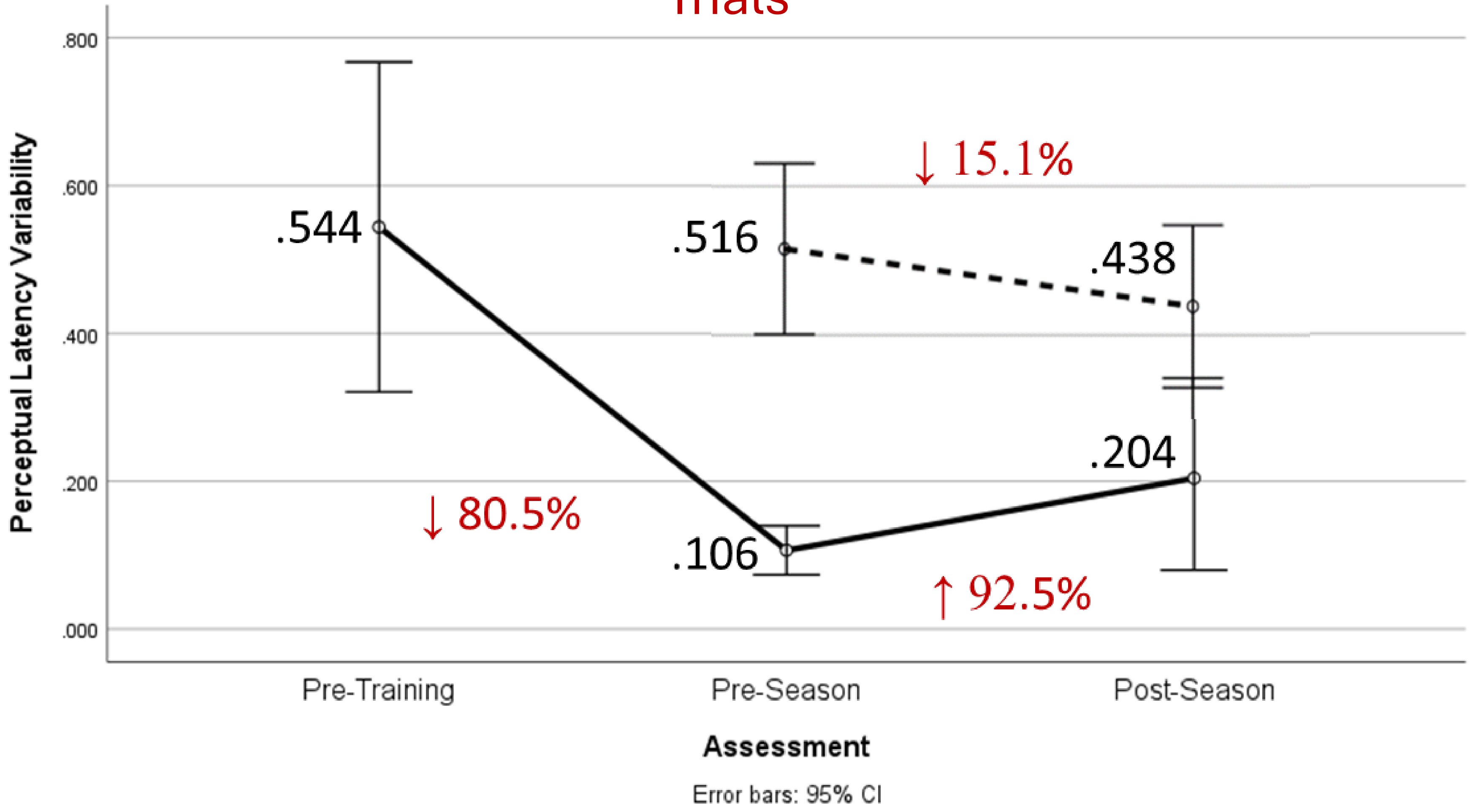
Neck Rate Correct per Second – Perceptual Latency

Rate Correct per Second = # Correct / Sum of Perceptual Latency for 40 Trials

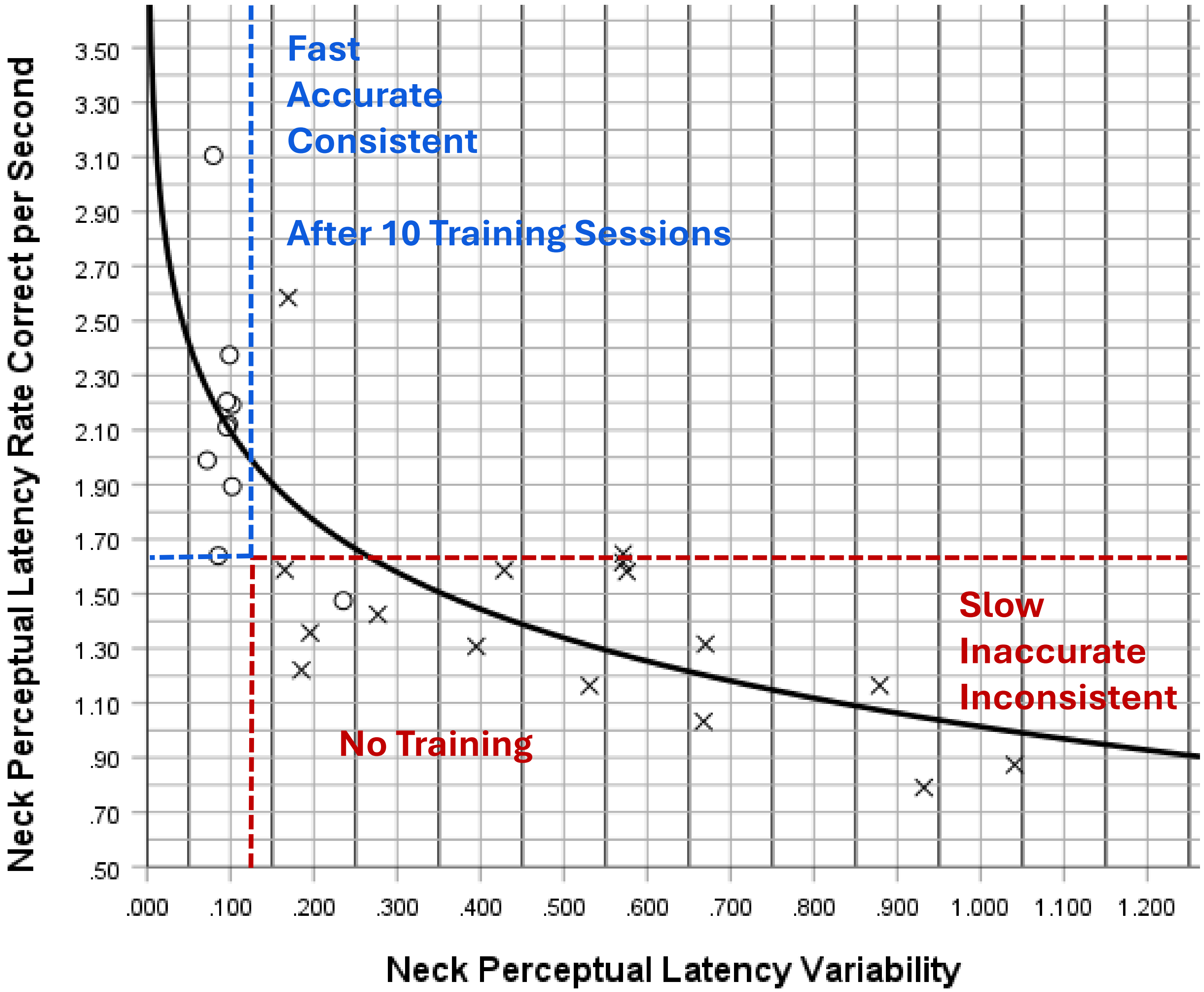


Neck Perceptual Latency Variability

Across-Trial Variability = Standard Deviation of Perceptual Latency over 40 Trials



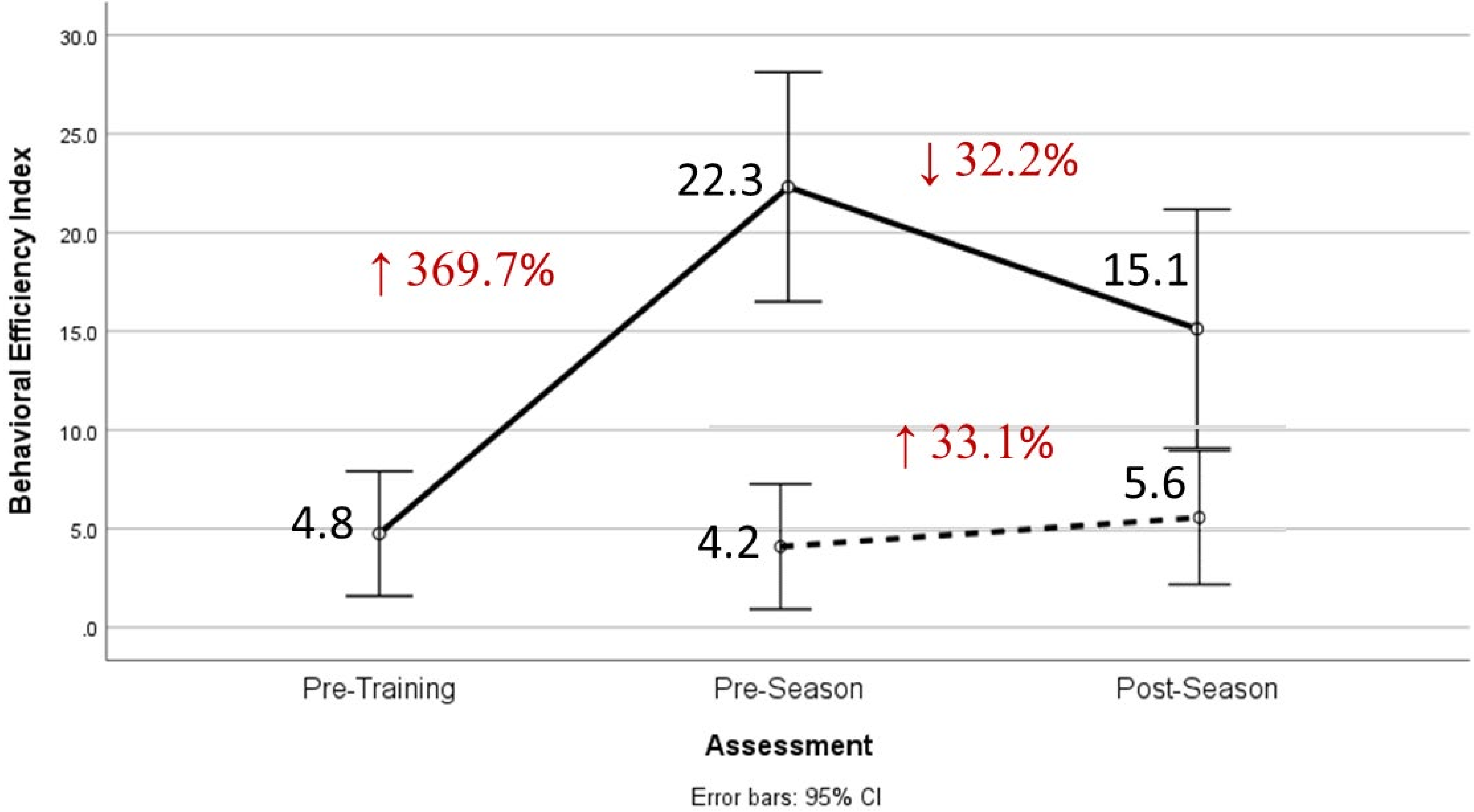
NCAA Div-I Women's Soccer Players (N=26)
Pre-Participation Assessment: Training Group (○) n=10 and No Training Group (X) n=16



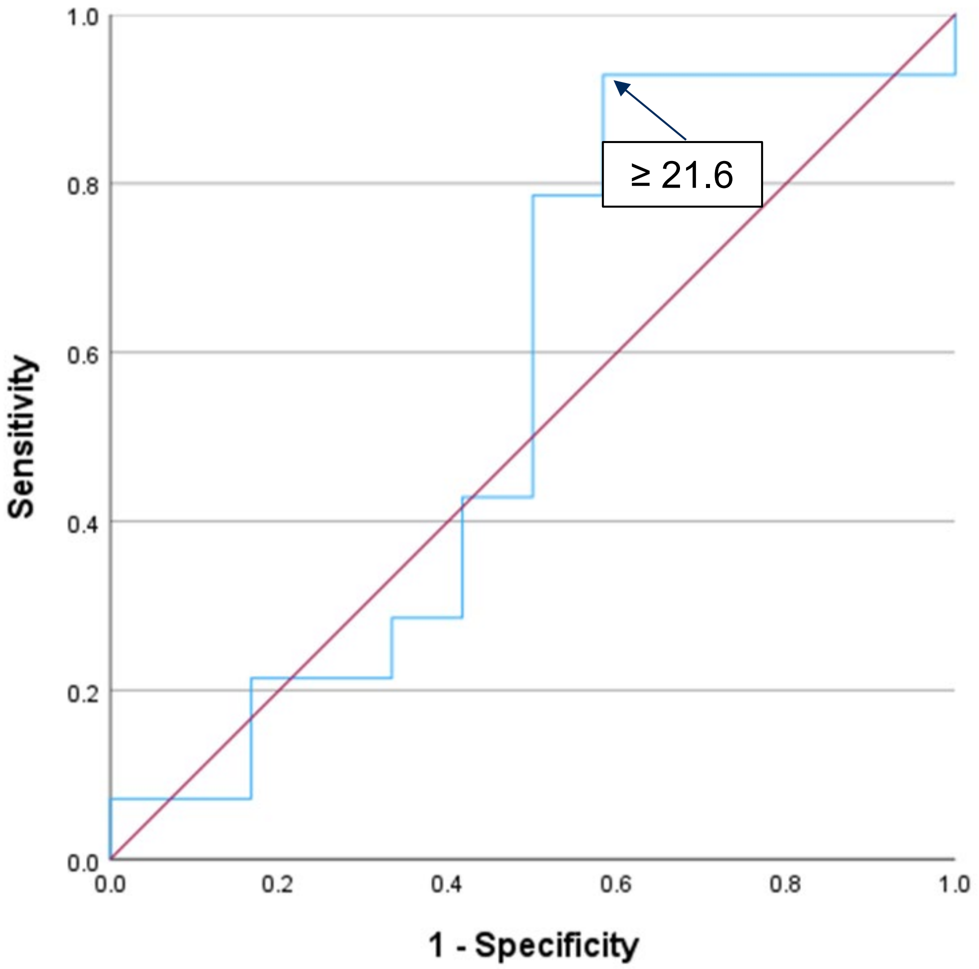
Spearman's Rho = –.795
$P < .001$

Neck Behavioral Efficiency Index – Perceptual Latency

Behavioral Efficiency Index = Rate Correct per Second / Across-Trial Variability



Neck Perceptual Latency Behavioral Efficiency Index



		Core or LE Injury		
		Yes	No	
Lo Neck PL BEI	≤ 21.6	13	7	PPV: 65%
	> 21.6	1	5	NPV: 83%
	Total	14	12	

Sensitivity: 93% **Specificity: 42%**

OR = 9.29 (95% CI: 0.90, 95.95)

Injury Area	Number
Ankle/Foot	0
Lower Leg	6
Knee	6
Thigh	3
Groin/Hip	3
Back	3
Total*	21

* 2 players sustained 3 injuries
3 players sustained 2 injuries
9 players sustained only 1 injury

Neck Perceptual Latency Behavioral Efficiency Index

		Core or LE Injury		
		Yes	No	
Lo Neck PL BEI	≤ 21.6	13	7	PPV: 65%
	> 21.6	1	5	NPV: 83%
	Total	14	12	

Sensitivity: 93% Specificity: 42%

OR = 9.29 (95% CI: 0.90, 95.95)

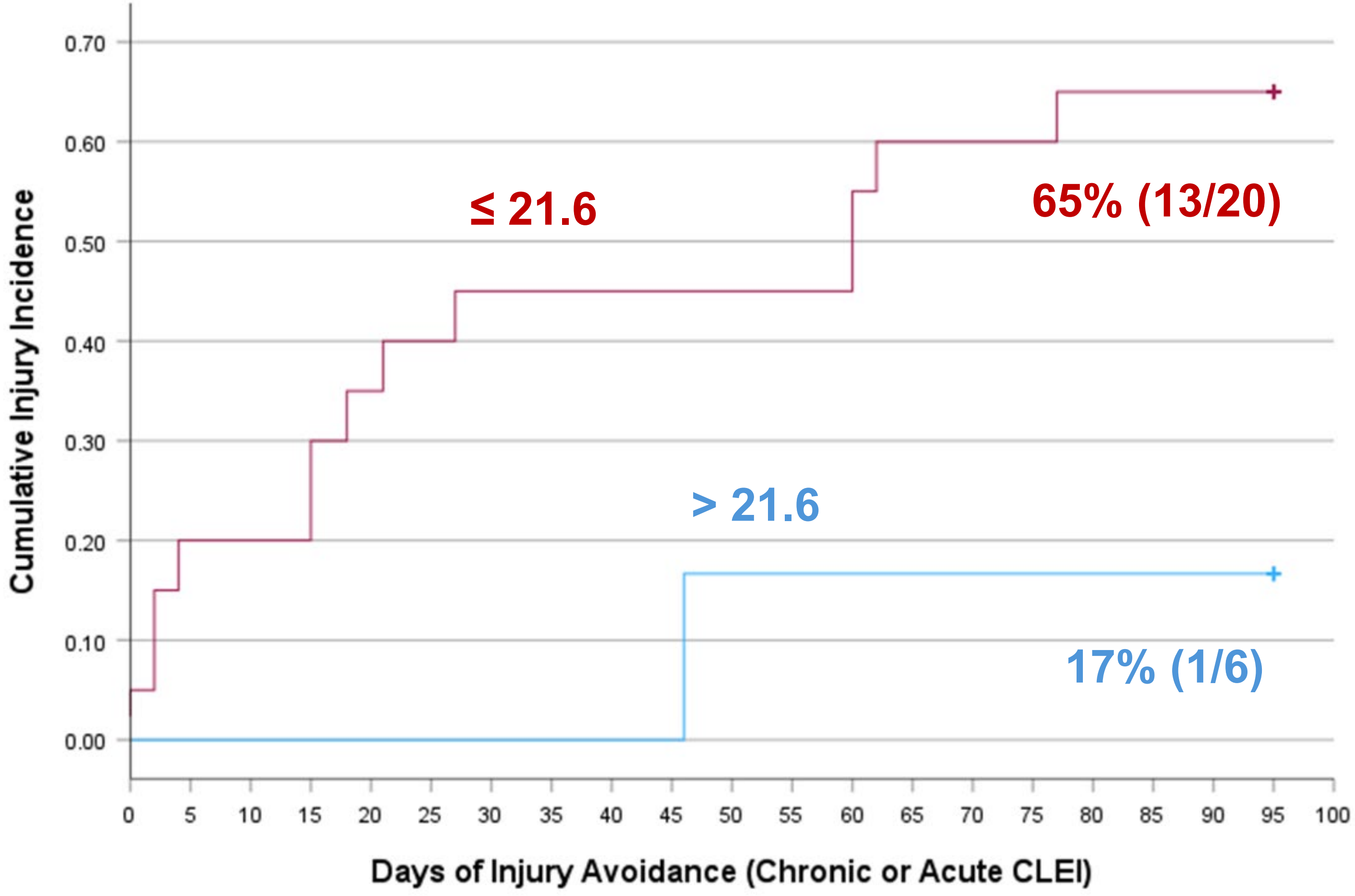
		Core or LE Injury		
		Yes	No	
Starter Status	Yes	10	6	PPV: 63%
	No	4	6	NPV: 60%
	Total	14	12	

Sensitivity: 71% Specificity: 50%

OR = 2.50 (95% CI: 0.50, 12.64)

Kaplan-Meier Time to Injury Analysis (Core or Lower Extremity Injury)

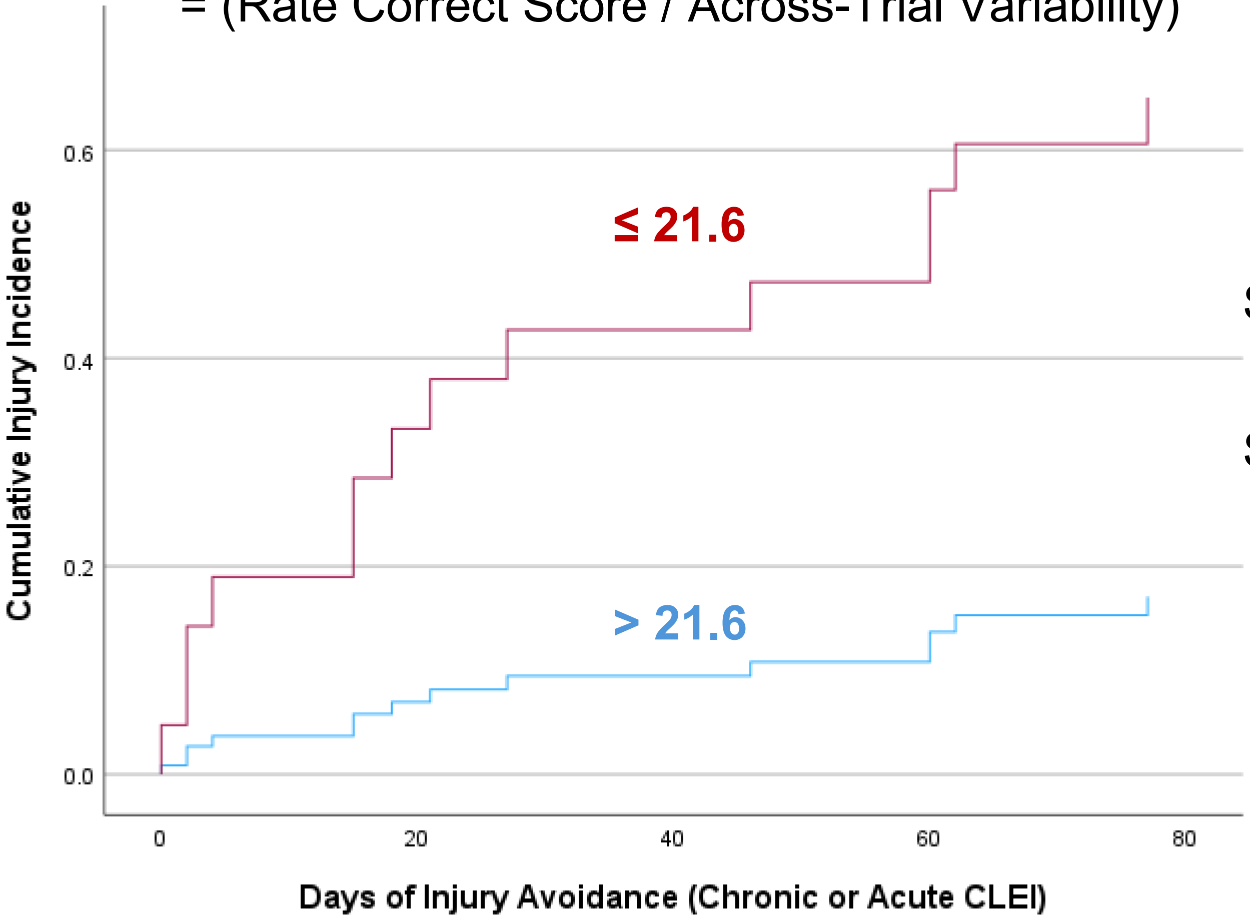
Neck Perceptual Latency Behavioral Efficiency Index
= (Rate Correct Score / Across-Trial Variability)



Mantel-Cox Log Rank
P = .059

Cox Regression Time to Injury Analysis (Core or Lower Extremity Injury)

Neck Perceptual Latency Behavioral Efficiency Index
= (Rate Correct Score / Across-Trial Variability)



	Predictor	HR	(95% CI)
Step 1	Neck PL BEI_≤ 21.6	5.43	(0.70, 42.36)
	Starter Status - Yes	1.15	(0.36, 3.72)
Step 2	Neck PL BEI_≤ 21.61	5.61	(0.73, 43.01)

Clinical Relevance

- Our findings affirm VR training potential to produce tangible benefits[6]
  - Cognitive abilities that may augment physical abilities (strength/power)[1,7]
- Perceptual decision making is foundational to all behaviors[8]
  - Injury avoidance likely depends on decisions that are rapid, accurate, and consistent
- Speed-accuracy tradeoff (RCS) and consistency across trials (PLV) are important metrics to quantify perceptual decision making capability
  - Behavioral efficiency index (RCS/PLV) reflects brain processing efficiency[9]

Clinical Relevance

- Despite lack of continued training over a 14-week period, the beneficial effects of pre-season training were largely retained
  - In-season training may ensure maintenance of optimal function

- Training should not focus exclusively on “physical” performance (strength, power, endurance, etc.)
  - Perceptual decision making appears to be a critical factor influencing sport performance capabilities and injury susceptibility

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