Stop the Guessing Game: Implementing a Criterion and Evidence-Based Functional Performance Testing Algorithm in Foot and Ankle Injuries

Stanford HEALTH CARE

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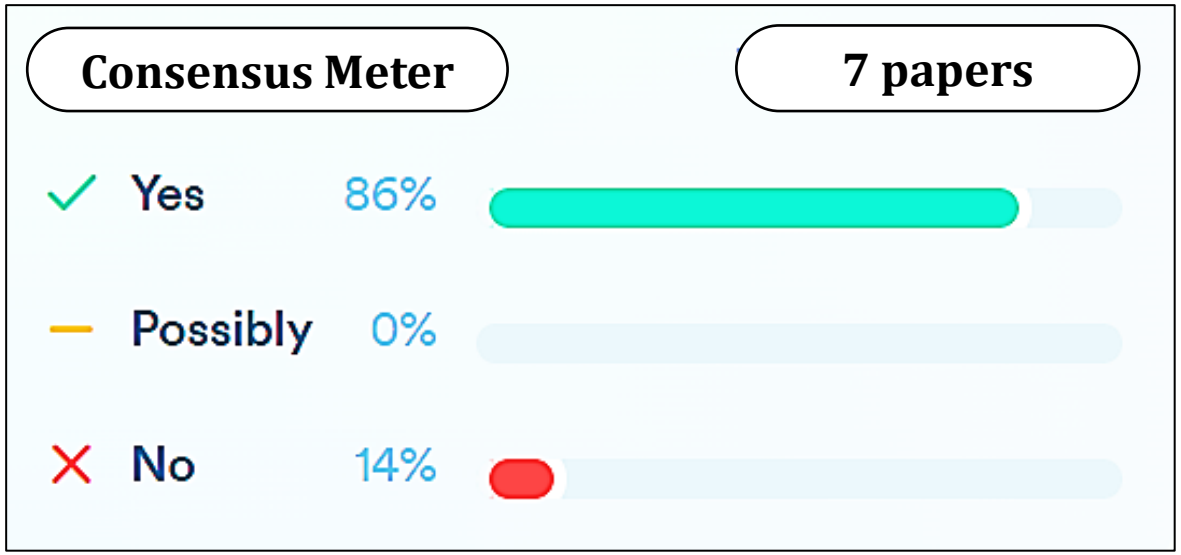
Postural Control

Significance of Postural Control

Does postural sway correlate with ankle injury risk?

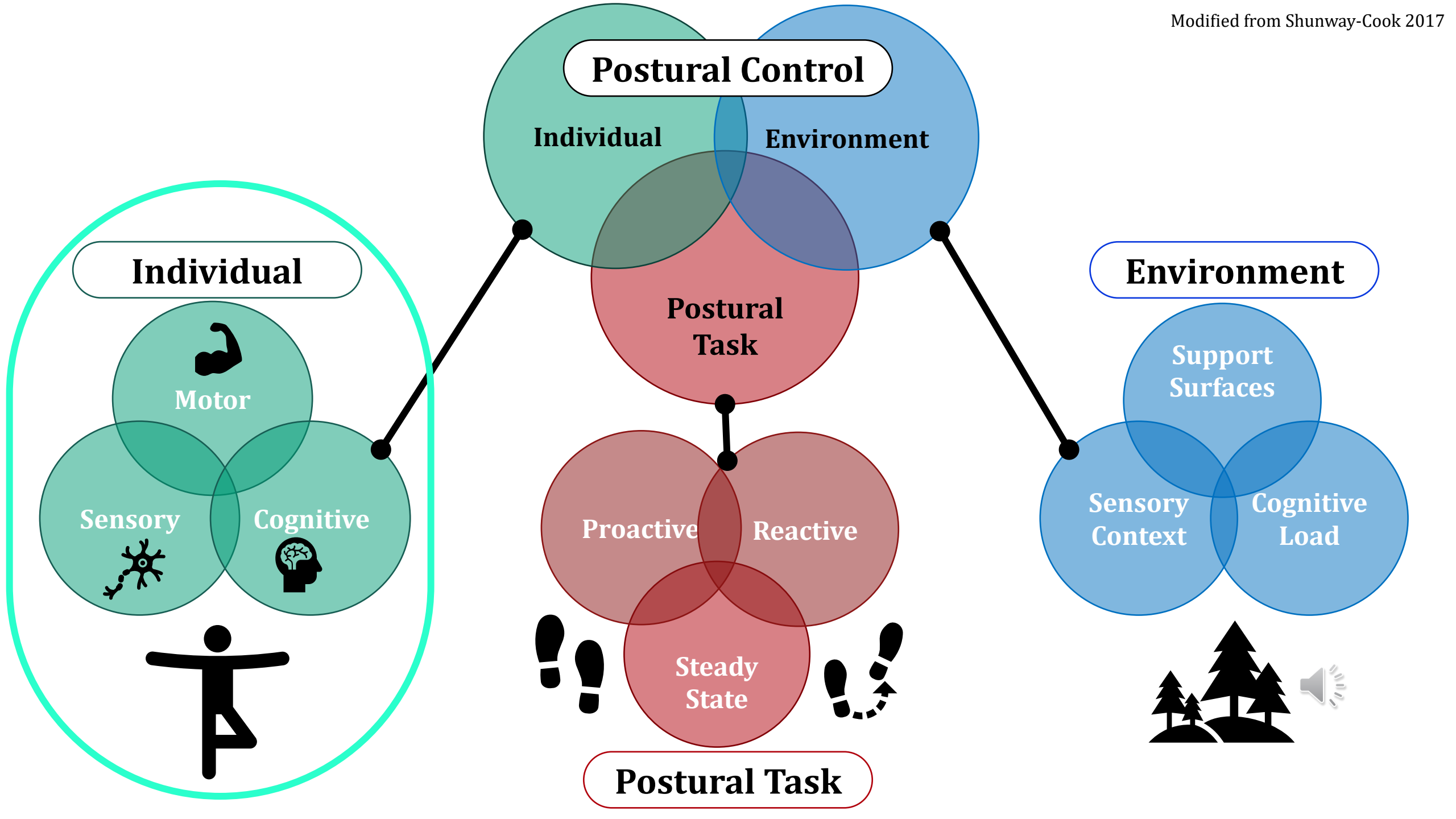
- **Postural Sway as a Risk Factor: Postural Sway and Ankle Injuries:** ⬆ variations in postural sway during a single-leg stance are linked to ⬆ incidence of ankle injuries.[1,2]
  - observed in high school basketball players, where those w/ ⬆ sway were **more likely** to sustain ankle sprains[1,2]
- **Assessment Tools:** The **Star Excursion Balance Test (SEBT)** and measurements of **center-of-gravity sway** have been effective in identifying individuals **at risk of ankle sprains**.



- These tools have shown that athletes with worse postural stability are more likely to sustain ankle injuries[3,7]
- **Balance assessments** can be used as **screening tools** to recommend balance training & potentially ⬇ **injury risk**[1,2]
- **Confounding Factors:** A history of ankle sprains can itself impair postural stability, making it a confounding factor in assessing the risk of future injuries. This highlights the importance of considering previous injuries when evaluating postural sway as a risk factor[3,8]

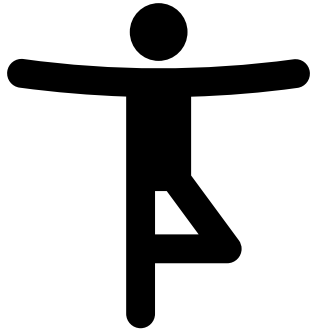
Wang 2016[1], McGuine 2000[2], Grassi 2000[3], Dingenen 2016[4], Santos 2014[5], Xue 2023[6] , Witchalls 2011[7], Kozinc 2021[8]

Modified from Shunway-Cook 2017



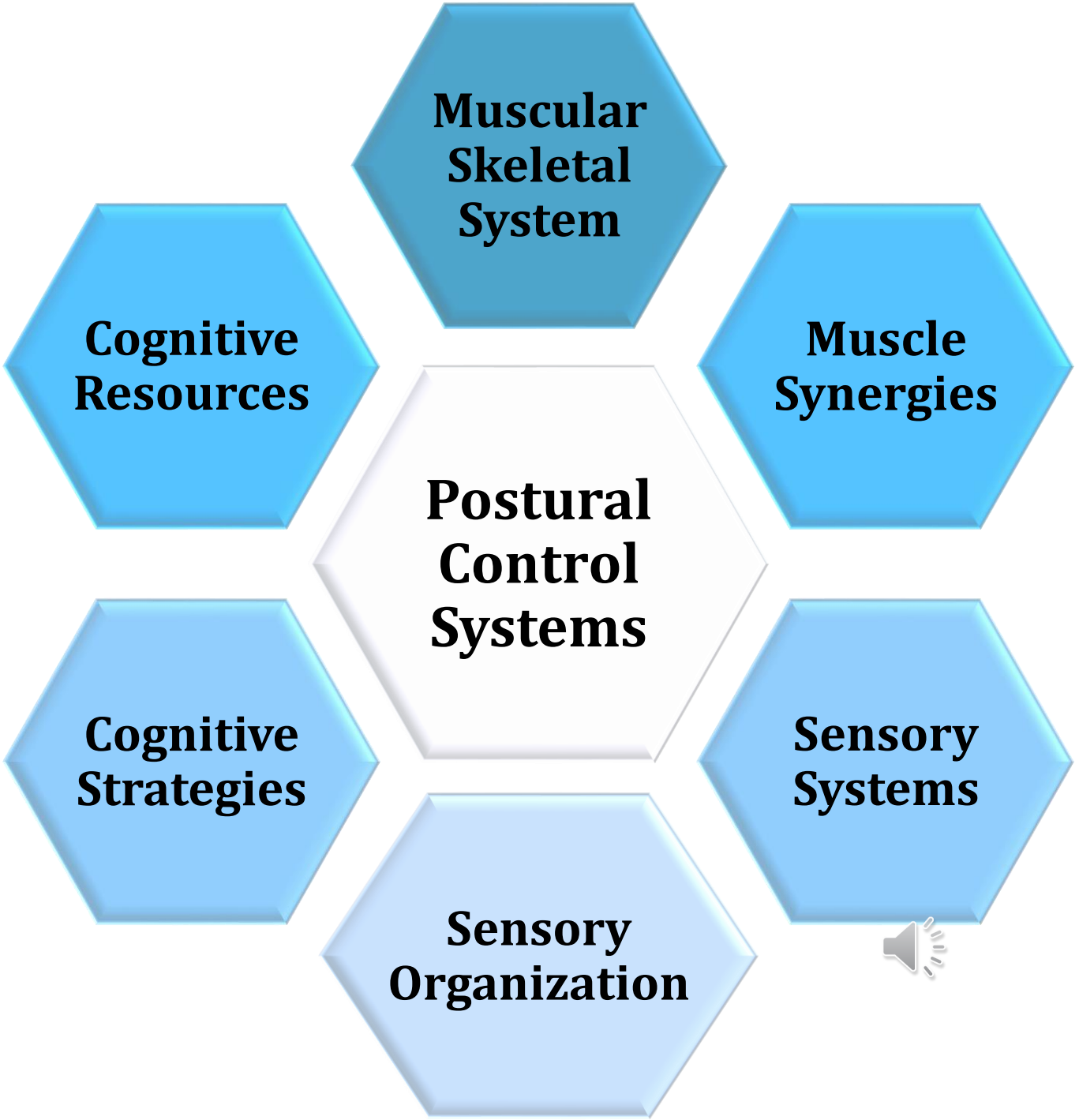
Postural Control: Independent Variables

Individual

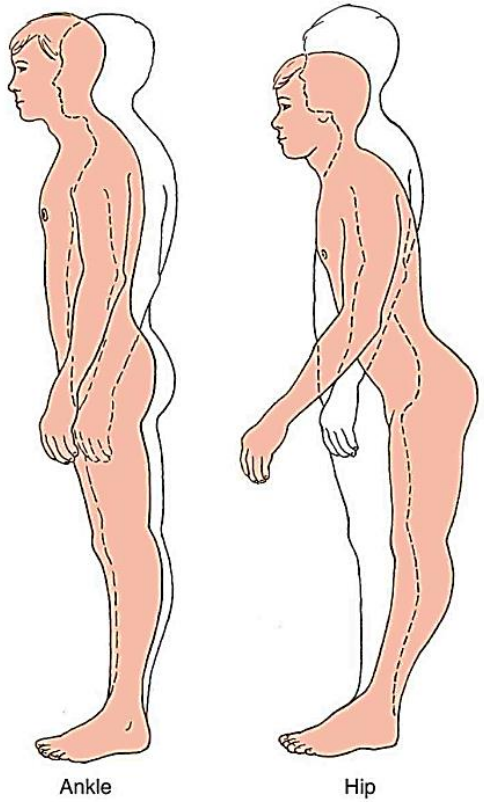


- *Age*
- *Sensory function (vision, vestibular system, proprioception)*
- *Certain Health Conditions*
- *Cognitive Function*
- *Muscle strength*
- *Joint Mobility*
- *Body Composition*

Chung 2022, Dusing 2010, Patti 2023



Postural Control: Constructs



Postural Control

Steady State Postural Control	Anticipatory Postural Control	Reactive Postural Control
the ability to control the COM relative to the BOS in (fairly) predictable & nonchanging conditions[1]	the ability to activate muscles for balance control in advance of voluntary movements[1]	ability to recover a stable position following an unexpected perturbation[1]
• *Time Duration* • *# of Faults/Δ Time* • *Postural Sway* • *Platform Deflection* • *Δ Center of Pressure* • *Etc.*	• *Distance reached* • *Postural Sway* • *Platform Deflection* • *Δ Center of Pressure* • *Etc.*	• *Postural Sway* • *Platform Deflection* • *Δ Center of Pressure* • *Time to stabilization* • *Etc.*

Shunway & Cook 2014[1], Sapega 1983[2], Rebelo 2022[3], Hathaway 2024[4]

Postural Control Testing Methods

Gold Standard	NeuroCom SOT Balance Master
	Lab Based Motion Capture
	Triaxial Force Plate(s)
Good	Stabilometer
	(Uniaxial) Force Plate(s)
Acceptable	App Based/Gyroscope
Sufficient	Battery of Field Tests
Questionable	Stand Alone Field Test

Isolated Muscle Performance Testing

Gold Standard	NeuroCom SOT Balance Master Lab Based Motion Capture Triaxial Force Plate(s)
Good	Stabilometer (Uniaxial) Force Plate(s)
Acceptable	App Based/Gyroscope
Sufficient	Battery of Field Tests
Questionable	Stand Alone Field Test

- **Good to Excellent reliability & validity**
- All **3D motion** & tri-axial **ground reaction vectors**
- Extensive **published research**

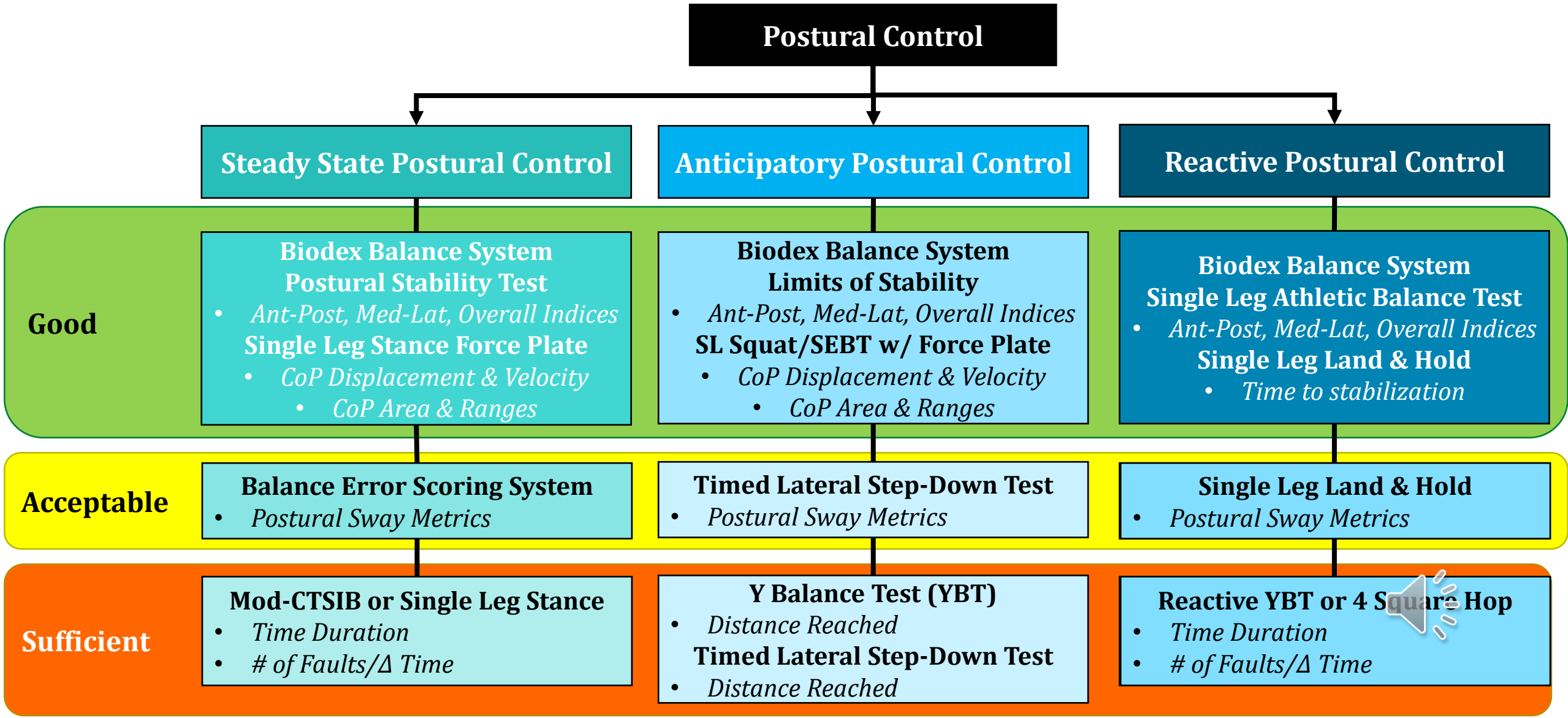
- **Good reliability & validity**
- **Dual axial** center of pressure changes
- Clinically friendly (with sufficient training)

- **Good to Acceptable** Reliability & Validity
- 2D postural sway capture
- Ease of clinical application (access & administration)

- **Acceptable** Reliability & Validity
- Require multiple assessment to ensure comprehensive postural control competency
- Ease of clinical application

- Acceptable reliability; questionable **validity**
- Insufficient to fully capture postural control competency
- Subject to ceiling and flooring effects

Postural Control: Constructs



Shunway & Cook 2014[1]

Postural Control Assessment Progression

Level 1*

Stable Surface Static Balance

Level 2*†

Unstable Surface Static Balance

Level 3¥

Stable Surface Dynamic Feedforward Balance

Level 4*†

Stable Surface Dynamic Feedback Balance

Level 5*¥†

Single Limb Ballistic Dynamic Balance

Types of Postural Control

1. Steady State*
2. Anticipatory (*feedforward*)¥
3. Reactive (*feedback*)†

Shunway-Cook 2017

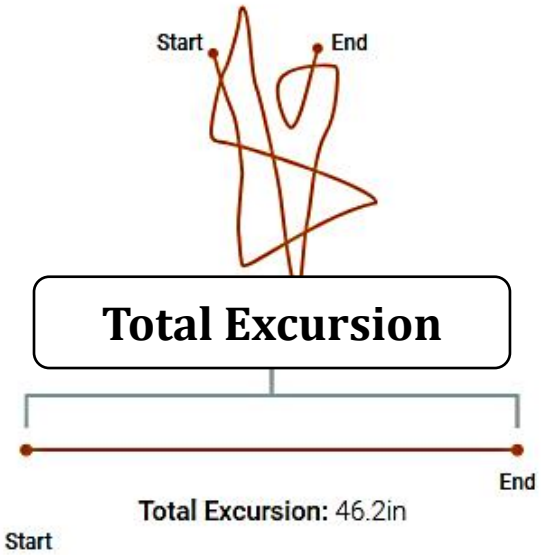
Postural Control Assessments

Good

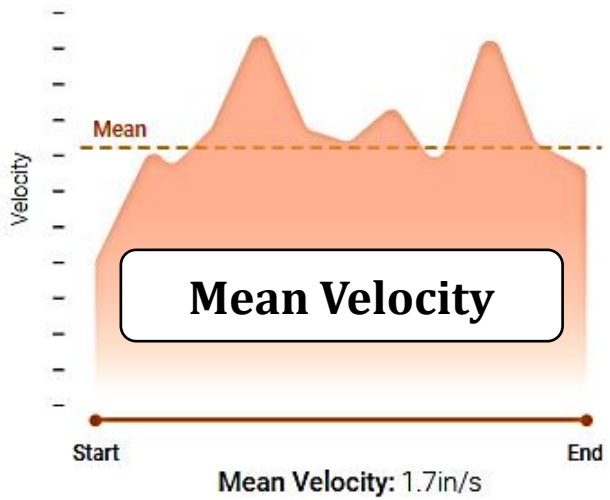
Level 1*
Stable Surface Static Balance

Knapp 2011[1], Snyder 2024[2], Van Humbeeck 2013[3], Linens 2014[4]

≤50% Eyes Open vs Closed[3]



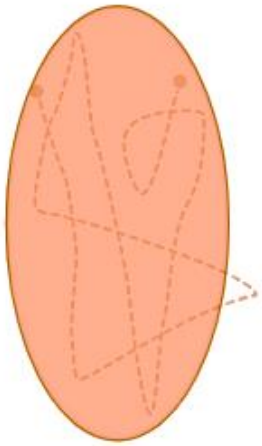
Cut off: ≤1.56 cm/s[4]



Level 1a
Time: 30 sec
Condition: Eyes Open

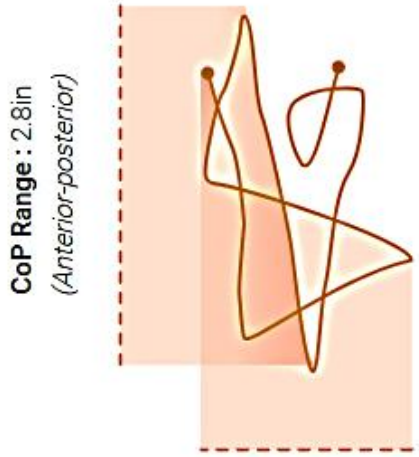
Level 1b
Time: 15 sec
Condition: Eyes Closed

≤80% Eyes Open vs Closed[3]



Area of Ellipse

Criteria: Age & Gender Specific Norms[4]



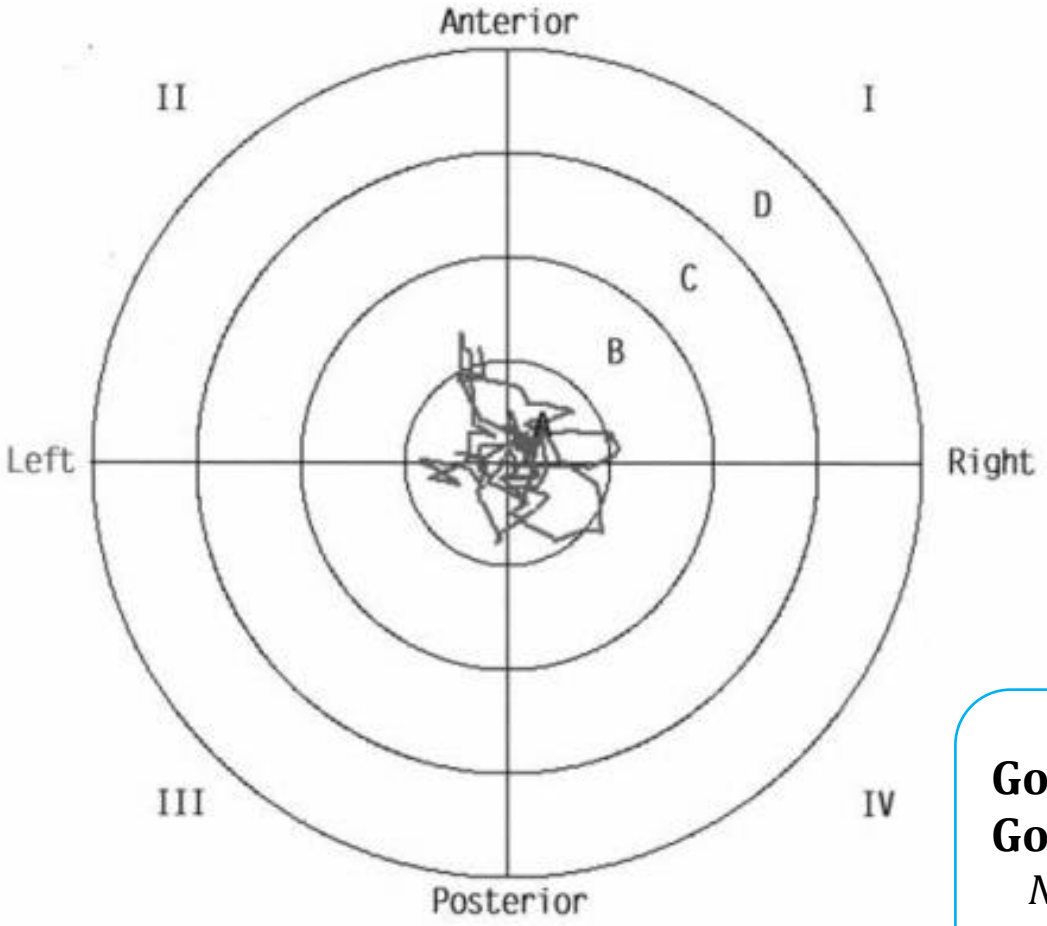
Center of Pressure Range

Note. Single-limb, quiet-standing force-plate measures of postural control may be **more useful for tracking outcome measures** in patients with **chronic ankle instability** than they are for serving as **diagnostic tools.**[1]

Postural Control Assessments

Good

Level 1*
Stable Surface Static Balance



- Zone A = 0-5°
- Zone B = 6-10°
- Zone C = 11 - 15°
- Zone D = 16 - 20°

Acceptable single limb balance
F: **≤ 2.2° of deflection**[1,2]
M: **≤ 3.0° of deflection**[1,2]

Duration: 30 sec
Level: 8

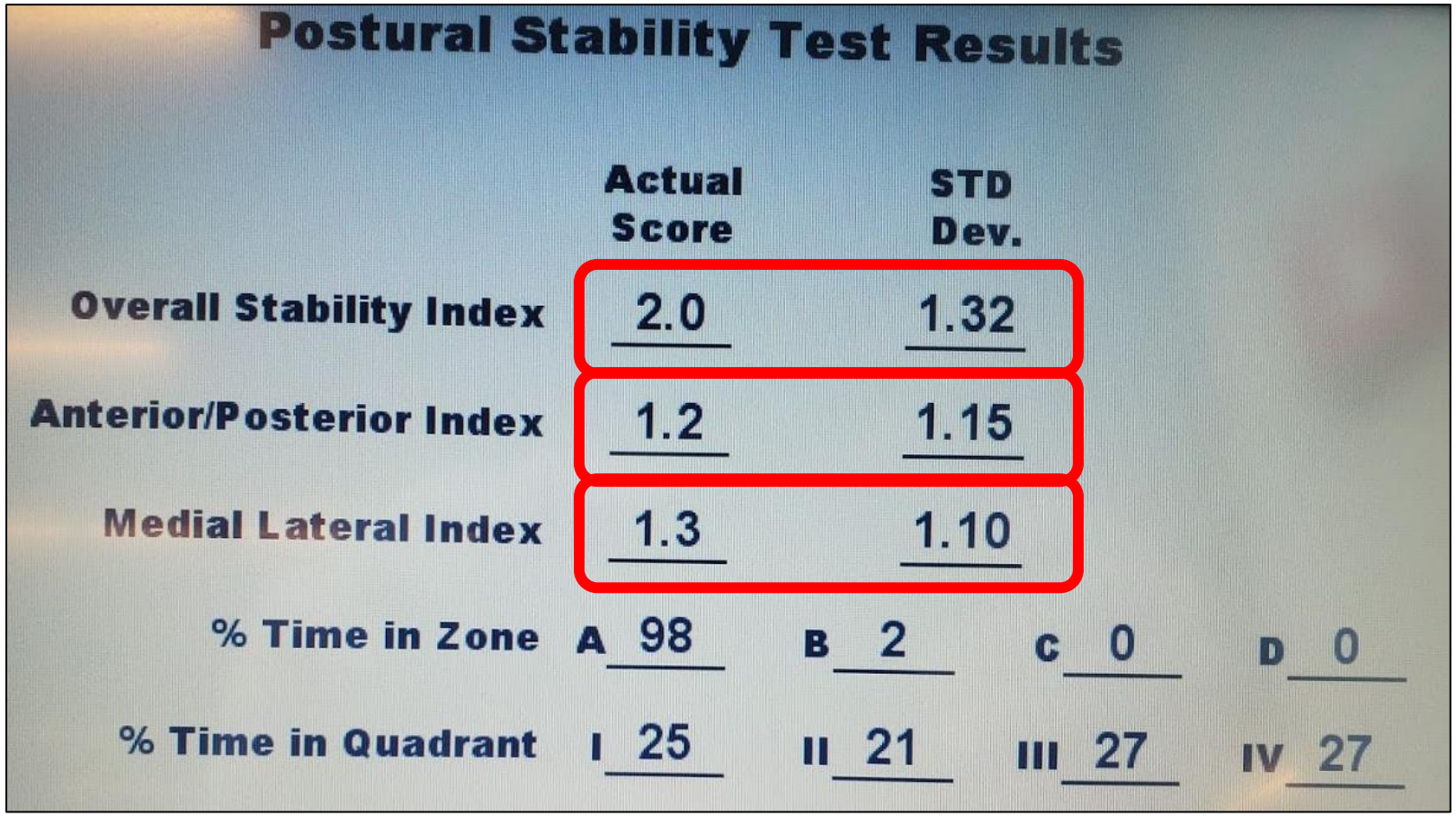
Goal 1: F: ≤ 2.2° | M: ≤ 3.0°
Goal 2: >95% LSI
NOTE: indices represent degree of displacement from level

Biodex Balance System SD Operation/Service Manual, Brotzman 2011[1], Myer 2006[2]

Postural Control Assessments

Good

Level 1*
Stable Surface Static Balance



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Biodex Balance System SD Operation/Service Manual, Brotzman 2011[1], Myer 2006[2]

Postural Control Assessments

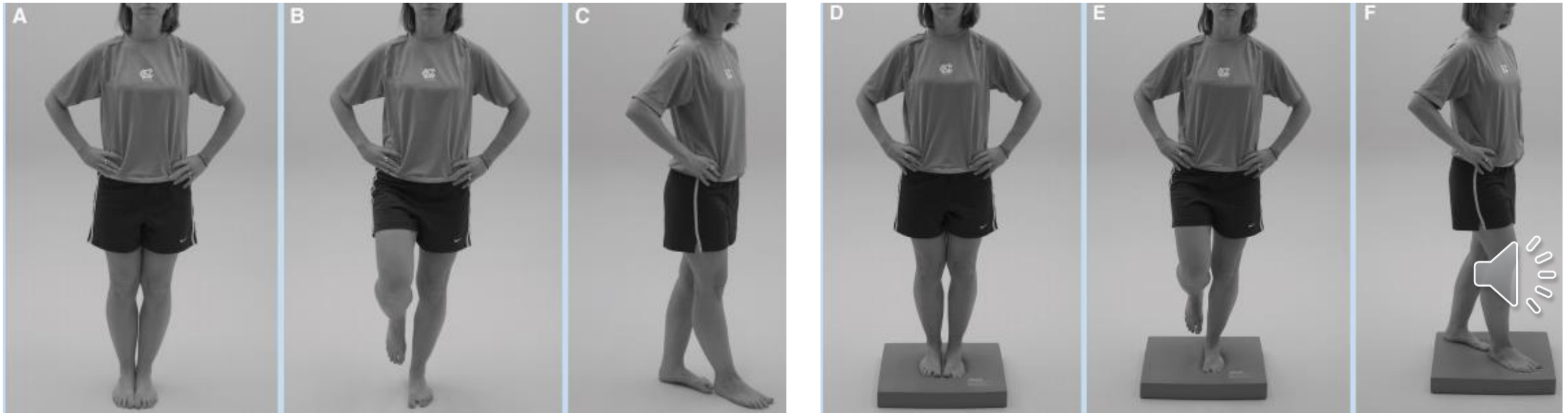
Level 1*
Stable Surface Static Balance

Level 2*†
Unstable Surface Static Balance

Sufficient

Balance Error Scoring System (BESS)	Firm		Foam	
	Eyes Open	Eyes Closed	Eyes Open	Eyes Closed
DL Stance				
SL Stance (dom)				
SL Stance (non-dom)				
Tandem (dom)				
Tandem (non-dom)				

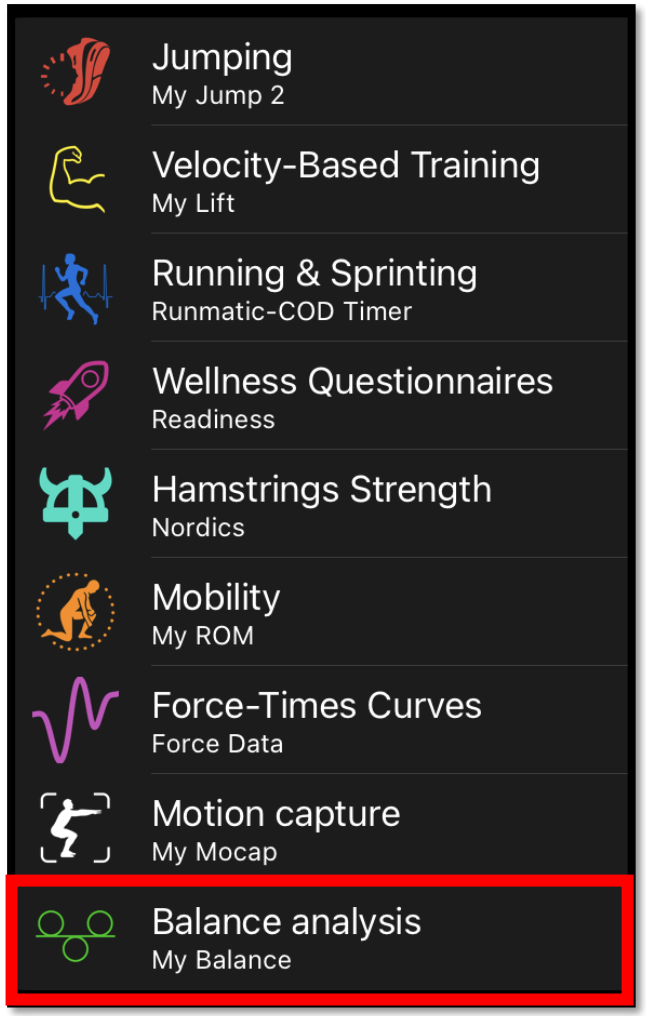
Bell 2011



Postural Control Assessments

Balance Error Scoring System

- **Equipment:** Airex, iPad, My Jump Lab App



My Jump Lab

LEAN FORWARD/BACK (X AXIS)
Range: -7.53 - 9.67 °
TURN LEFT/RIGHT (Y AXIS)
Range: -0.02 - 5.06 °
LATERAL INCLINATION (Z AXIS)
Range: -15.08 - 9.14 °

Level 1*

Stable Surface Static Balance

Acceptable

Level 2*†

Unstable Surface Static Balance

sway

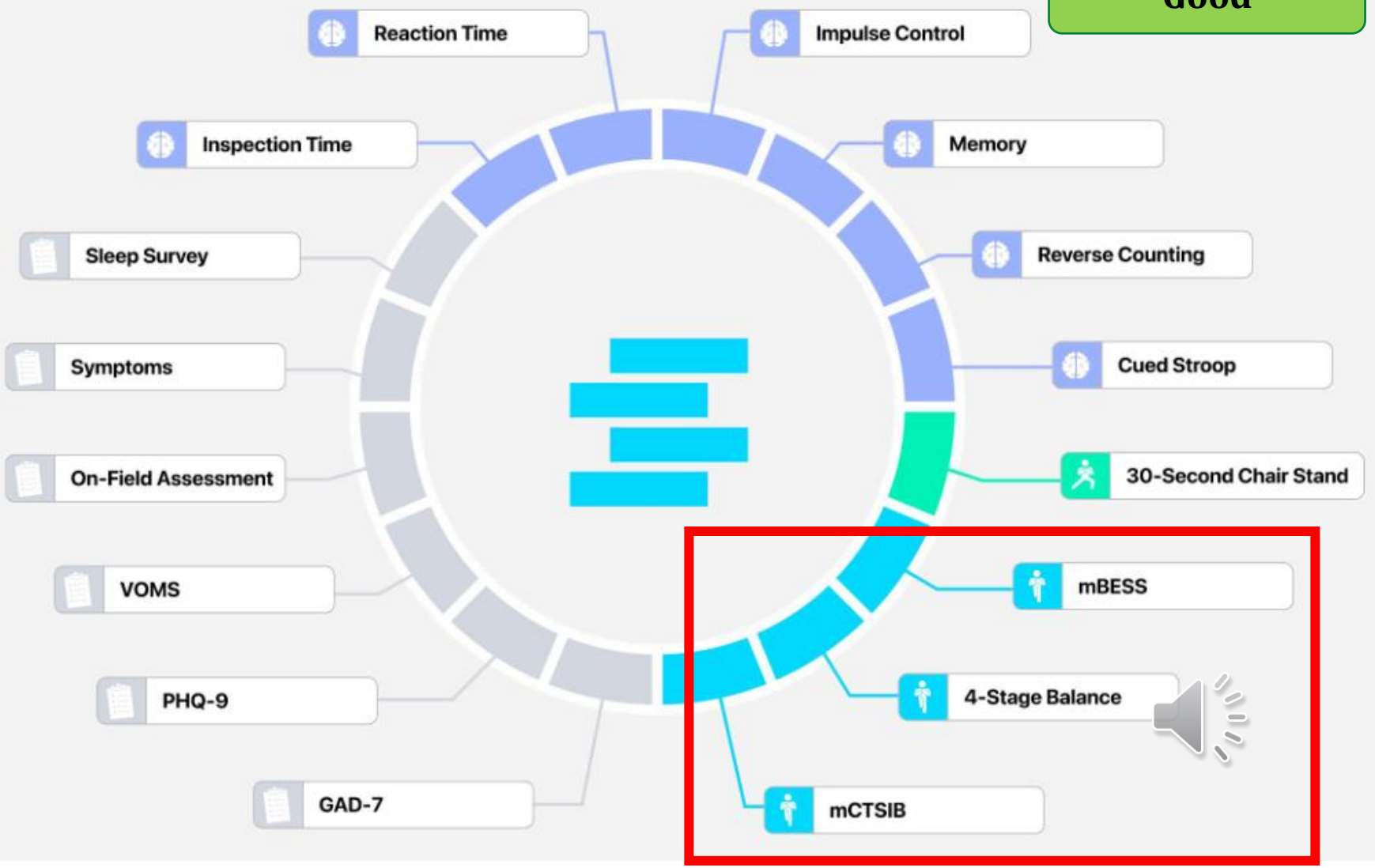
Good

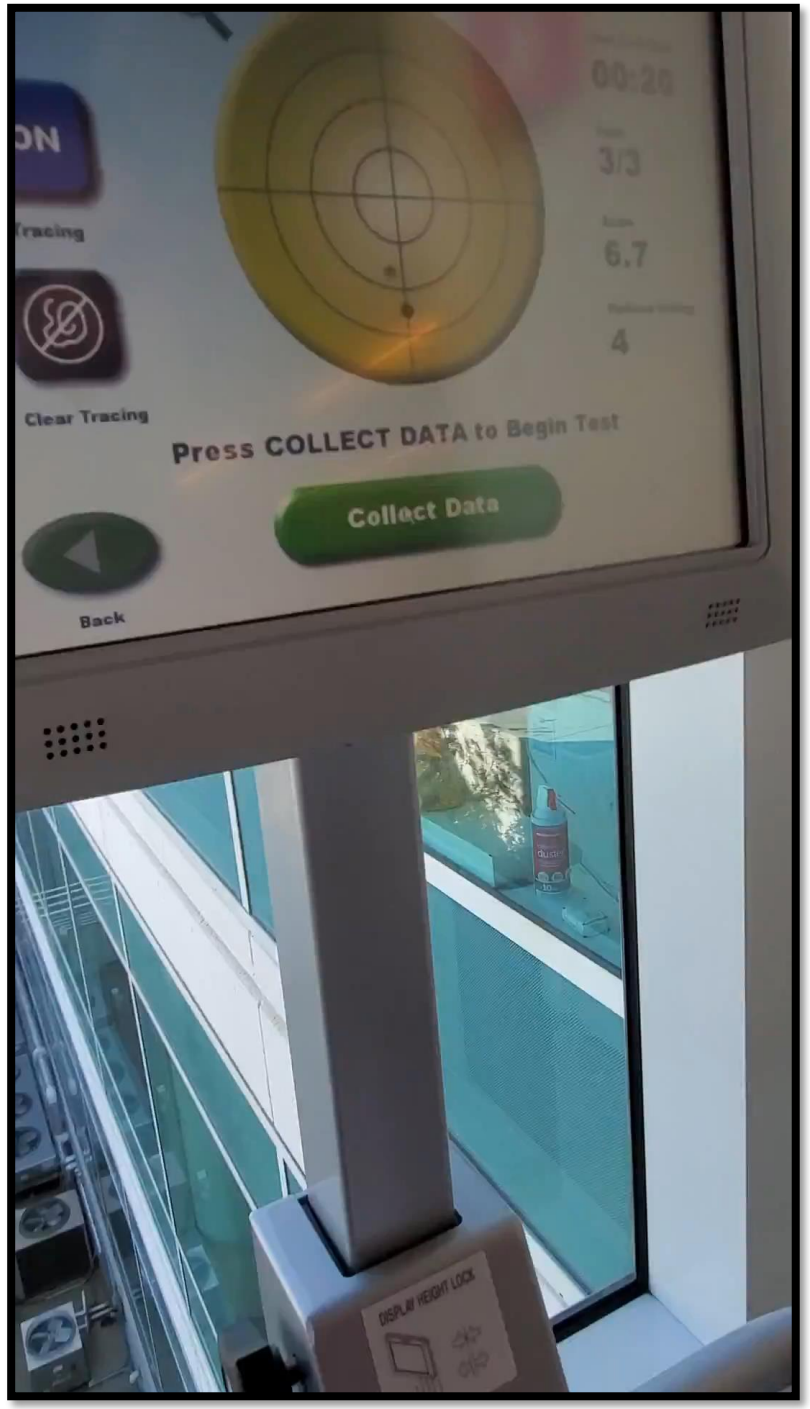
Sway Tests

- Balance
- Cognition
- Function
- Surveys

Sway is proud to meet all NCAA requirements for Baseline/Incident Testing

- ✅ Symptom Assessment
- ✅ Cognitive Assessment
- ✅ Balance Exam





Postural Control Assessments

Level 2*†

Unstable Surface Static Balance

Good

Biodex Balance System SD
Operation/Service Manual

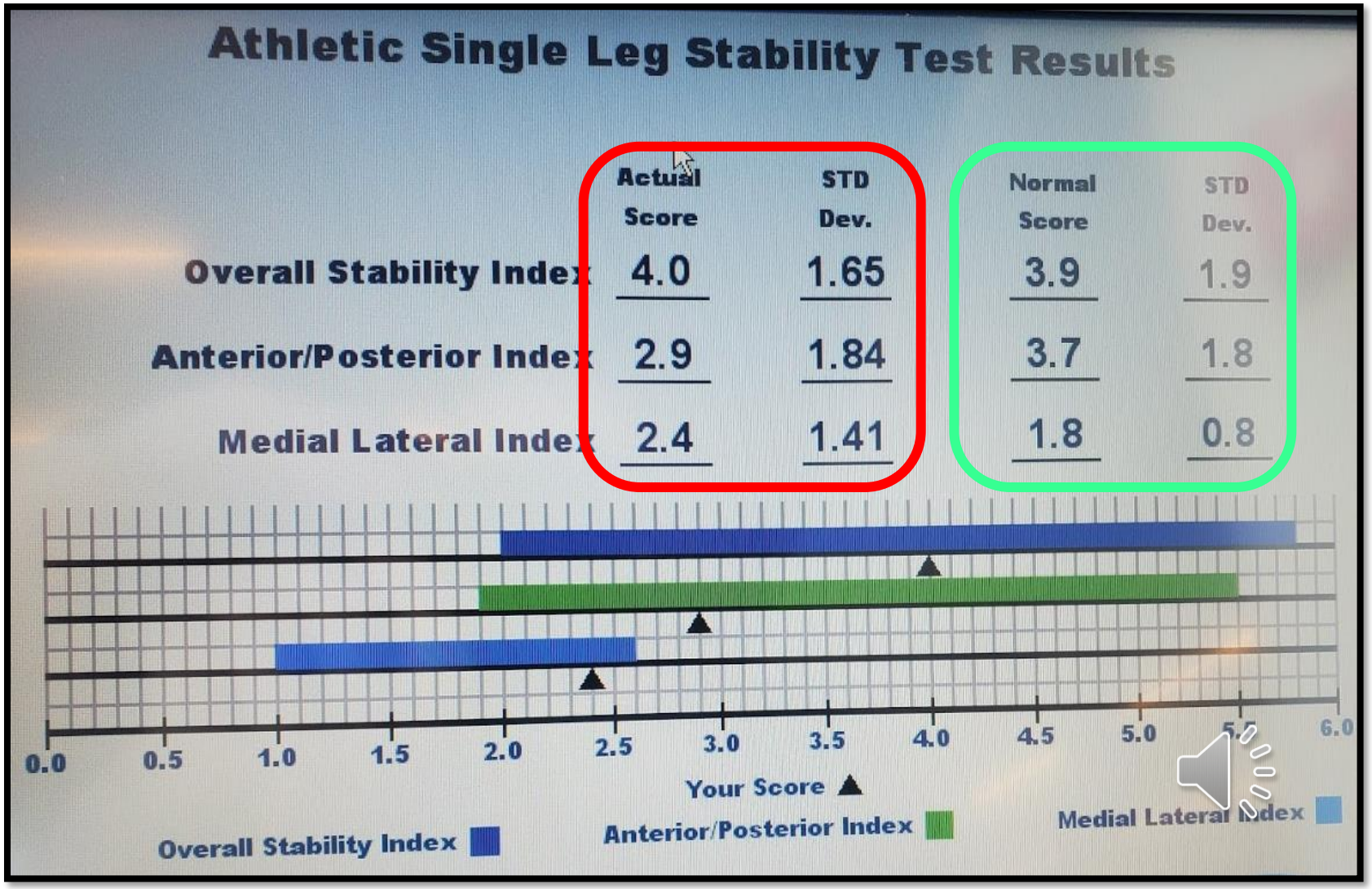
Postural Control Assessments

Good

Level 2*†
Unstable Surface Static Balance

GOAL 1:
EXCEED NORMAL SCORES
1. Overall Stability
2. ANT/POST Index
3. MED/LAT Index

GOAL 2:
100% LSI
1. Overall Stability
2. ANT/POST Index
3. MED/LAT Index



Biodex Balance System SD Operation/Service Manual

Postural Control Assessment Progression

Level	Suggested Test(s)	Metrics

Van Humbeeck 2013[1], Springer 2007[2], Knapp 2011[3], Linens 2014[4], Biodex Balance System SD Operation/Service Manual[5], Brotzman 2011[6], Myer 2006[7]

Postural Control Assessment Progression

Level	Suggested Test(s)	Metrics
Level 3 Stable Surface Dynamic Feedforward Balance		

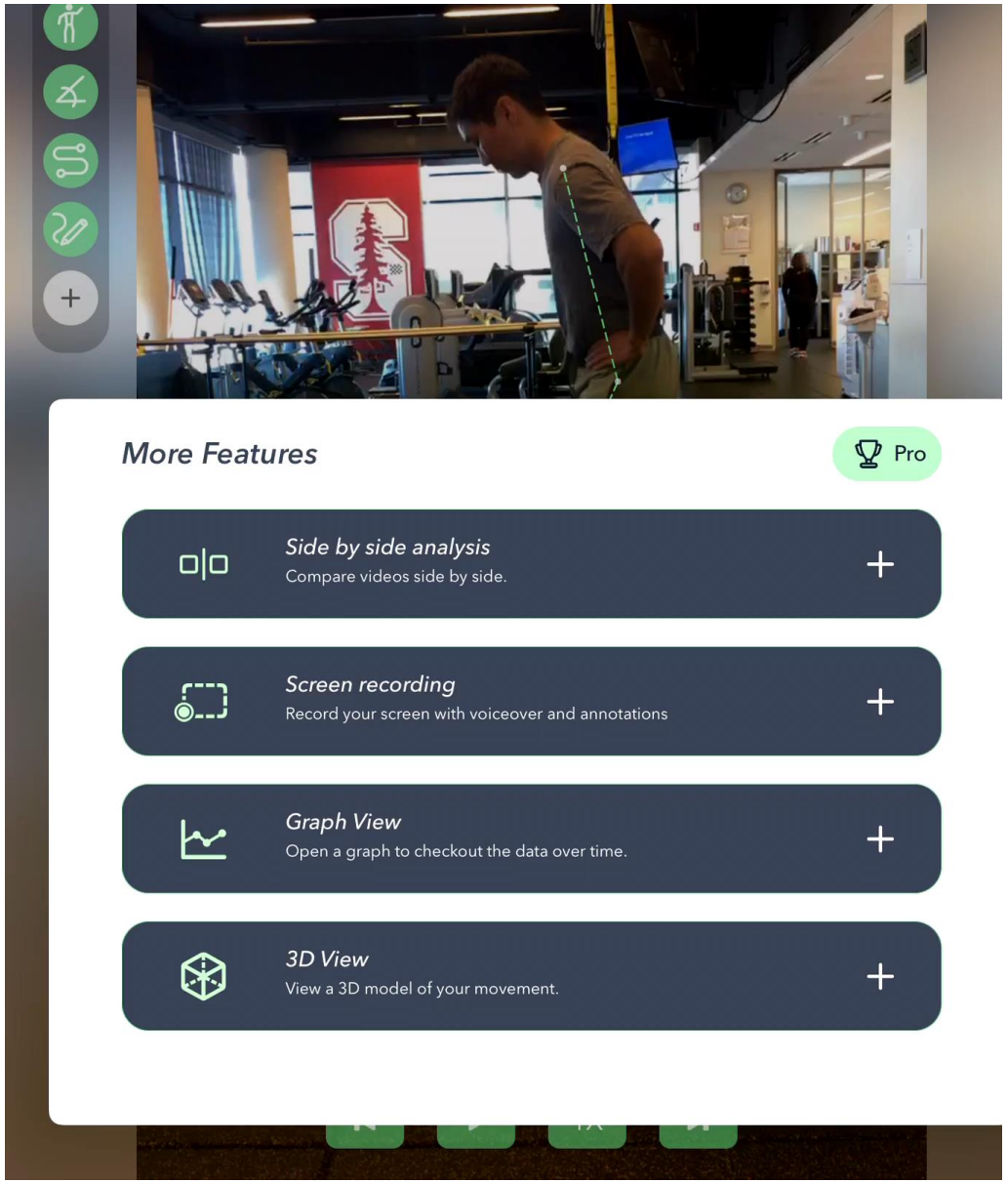
Note. *Rehab2Perform Software is available to provide individual specific norms and cutoffs that are gender, age, and sport specific. Functional Movement Systems[1], Smith 2015[2], Plinsky 2009[3], Alnahdi 2015[4], Jagger 2024[5], Haitz 2014[6]

Postural Control Assessments

Level 3¥

Stable Surface Dynamic Feedforward Balance

Sufficient



Step Height: 60-70° Knee
Tempo: 80 bpm
Outcome: time (s)
Pass Criteria:

- ≥90% Limb Symmetry
- ≥90% Norms

Stop Criteria:

- 3 Movement Faults*
- Onset of Pain
- Volitional Fatigue

Males

Dominant: 114 s
Non-Dominant: 126 s

Females

Dominant: 131 s
Non-Dominant: 122 s

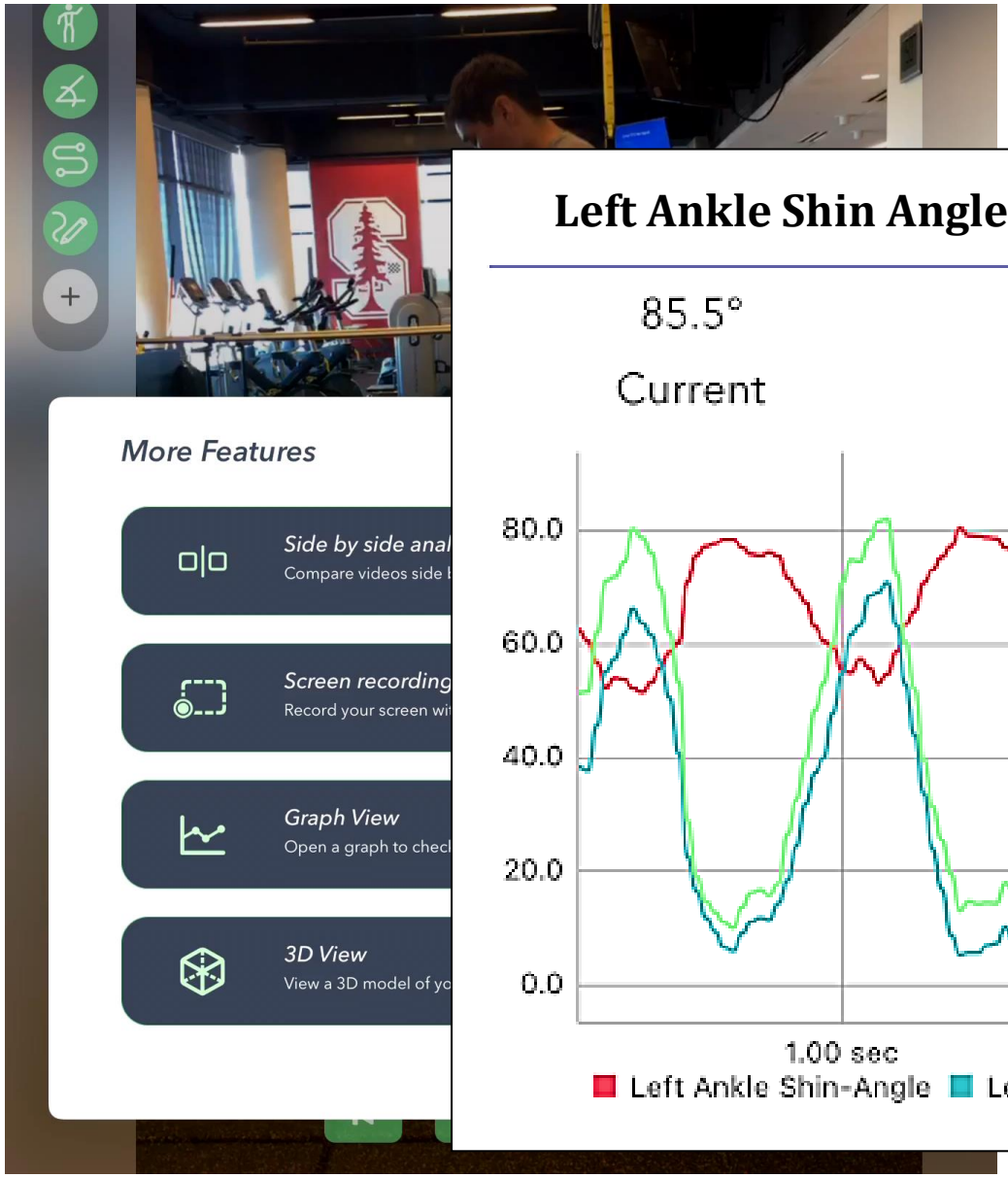
Haitz et al 2014

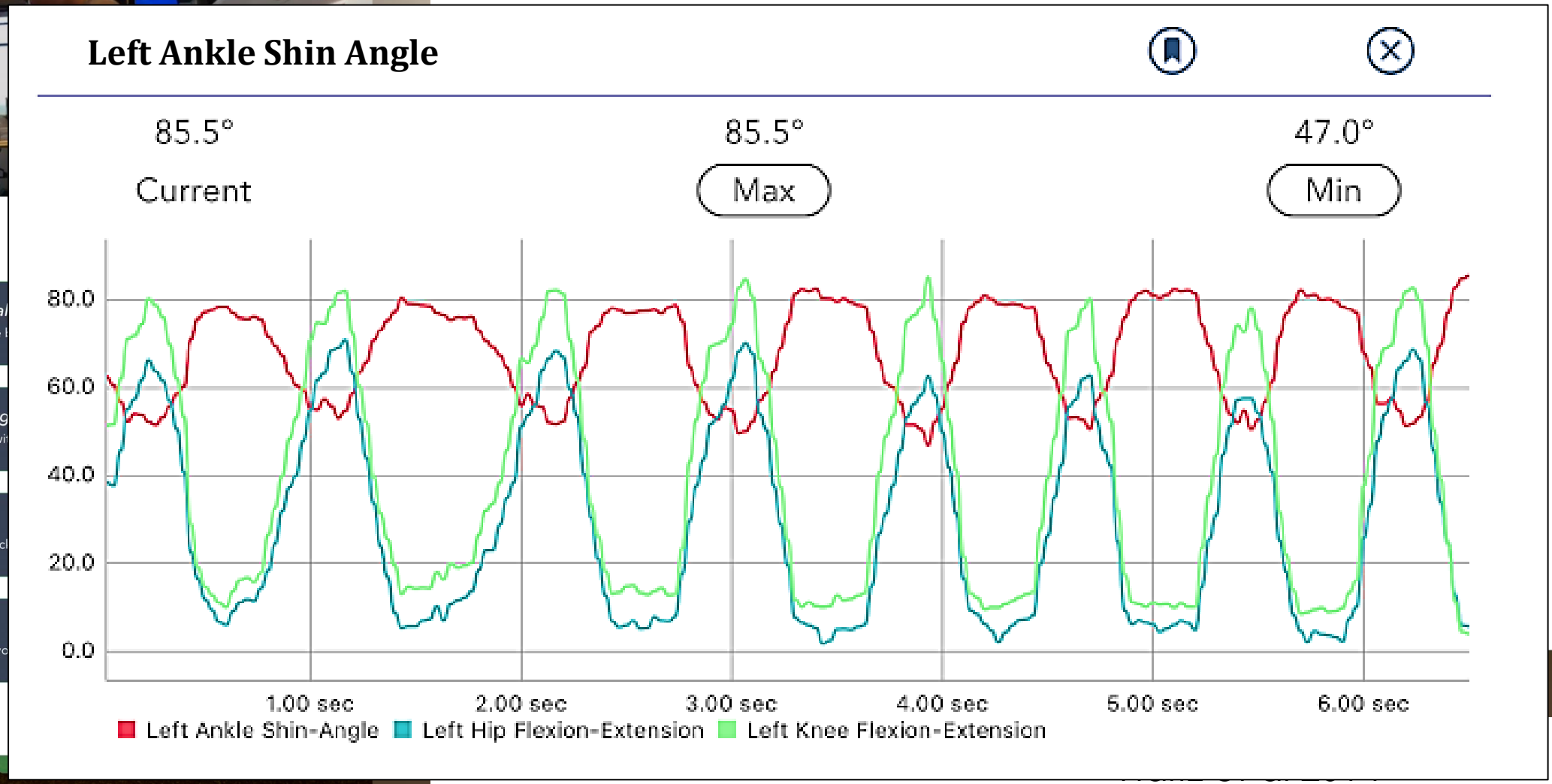
Postural Control Assessments

Level 3¥

Stable Surface Dynamic Feedforward Balance

Sufficient





Postural Control Assessments

Level 4*†

Stable Surface Dynamic Feedback Balance

The Reactive (Y) Balance Test

Sufficient

Accuracy Score (%) =

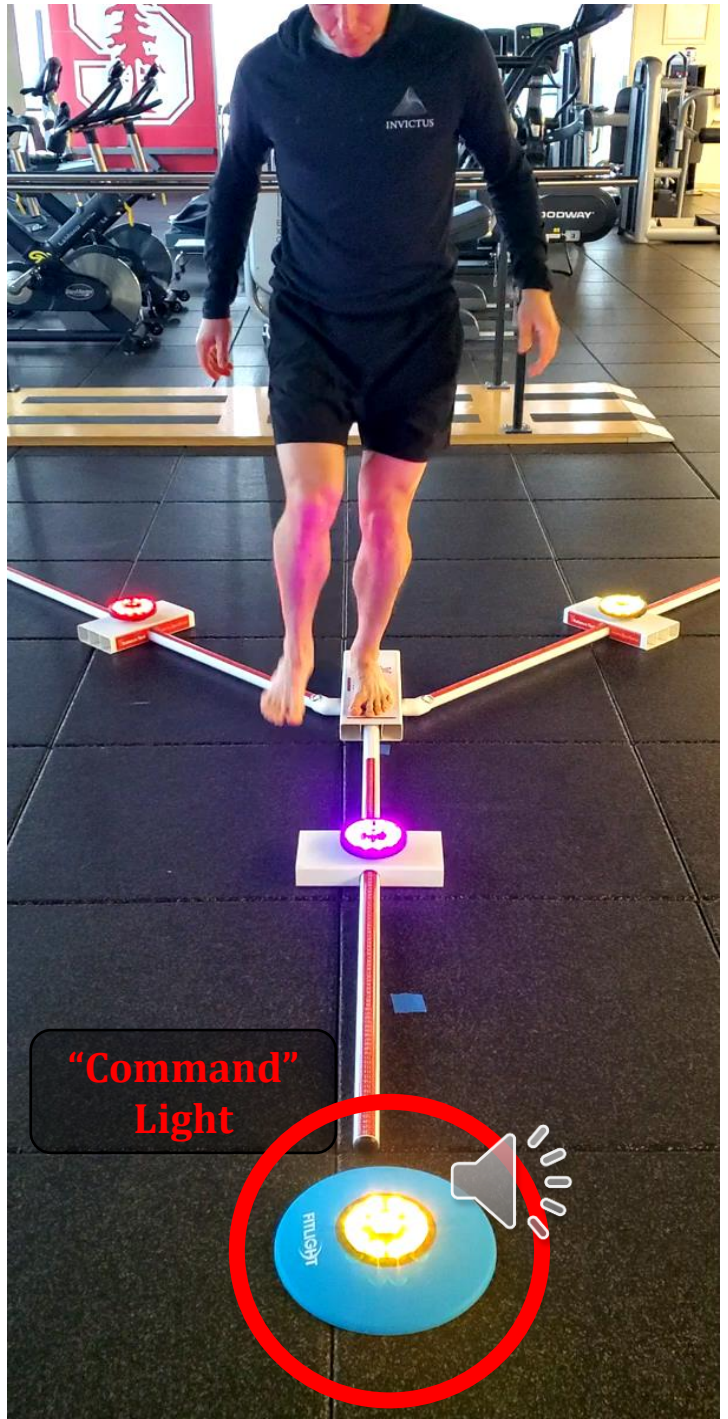
$$\frac{Total\ \#\ of\ Stimuli - (Missed\ Stimuli + Multiple\ Attempts + Decision\ Errors)}{Total\ \#\ of\ Stimuli}$$

Visuomotor Reaction Time = average time (ms) to exstinguish the appropriate light during each stimuli

Stimuli #	✓	✗	+1	⤮	🧍
1					
2					
3					

Hits	Misses	Avg. reaction	Time
21	1	1.3	43.0

Verschueren 2019, Maricot 2024



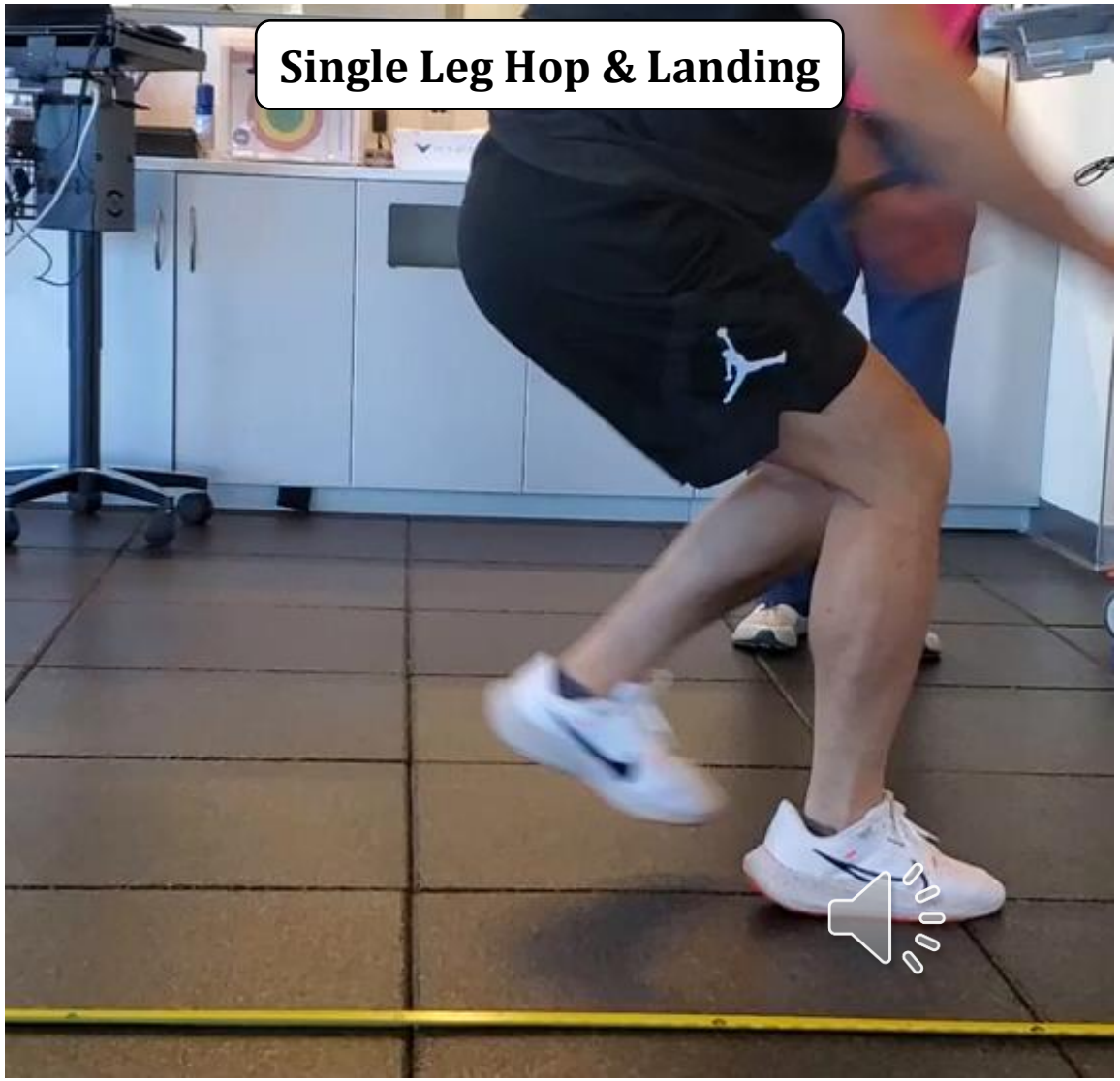
Postural Control Assessments

Good

Level 5*¥†
Single Limb Ballistic Dynamic Balance

Single Leg Land & Hold

Single Leg Hop & Landing



Single Leg Hop & Return

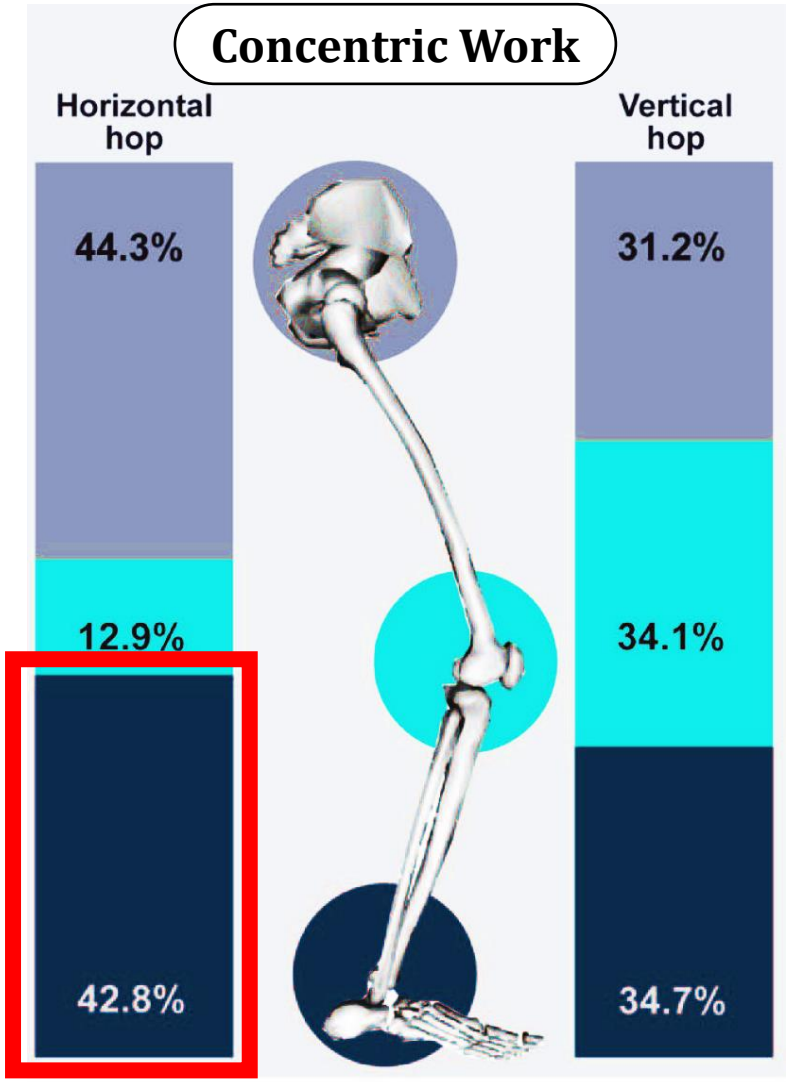
VALD 2024[1] , Bond 2017[2], Garcia-Masso 2019,[3] Fransz 2015,[4] Fransz 2016[5], Ross 2005[6] Ross 2008[9]

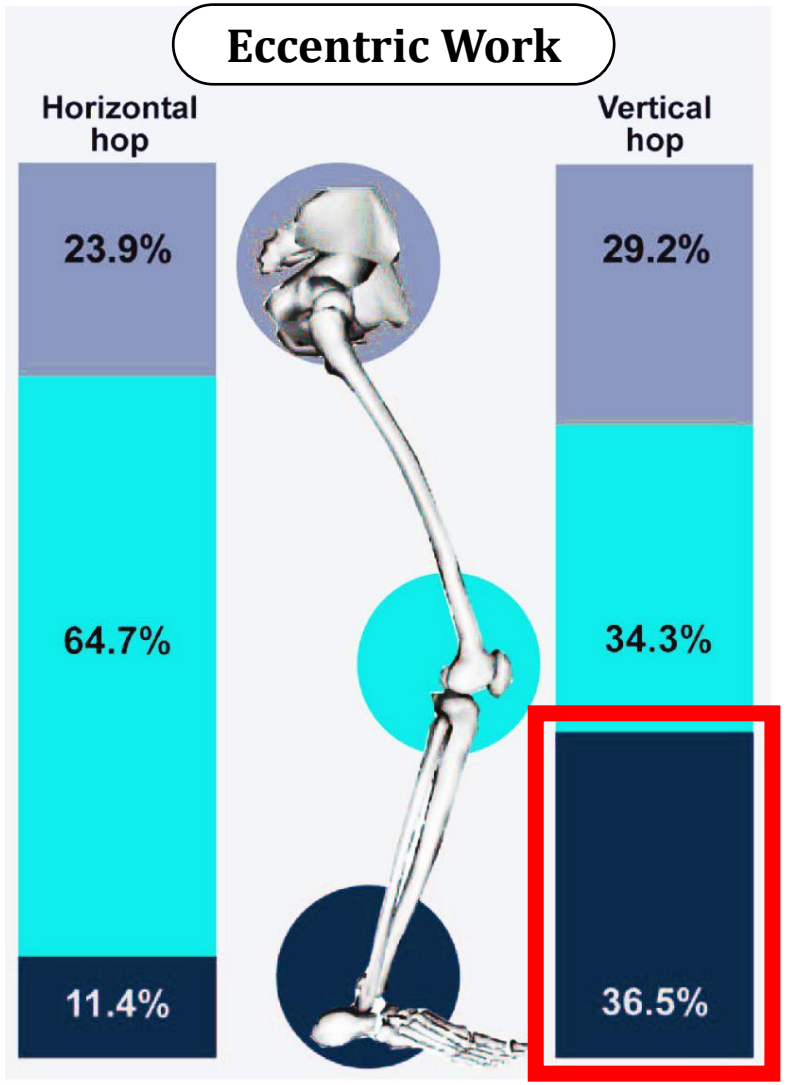
Postural Control Assessments

Level 5*¥†

Single Limb Ballistic Dynamic Balance

Single Leg Land & Hold (Time to Stabilization)





https://pmc.ncbi.nlm.nih.gov/articles/PMC9262956/

Maniar 2022[1]

Postural Control Assessment Progression

Level	Suggested Test(s)	Metrics

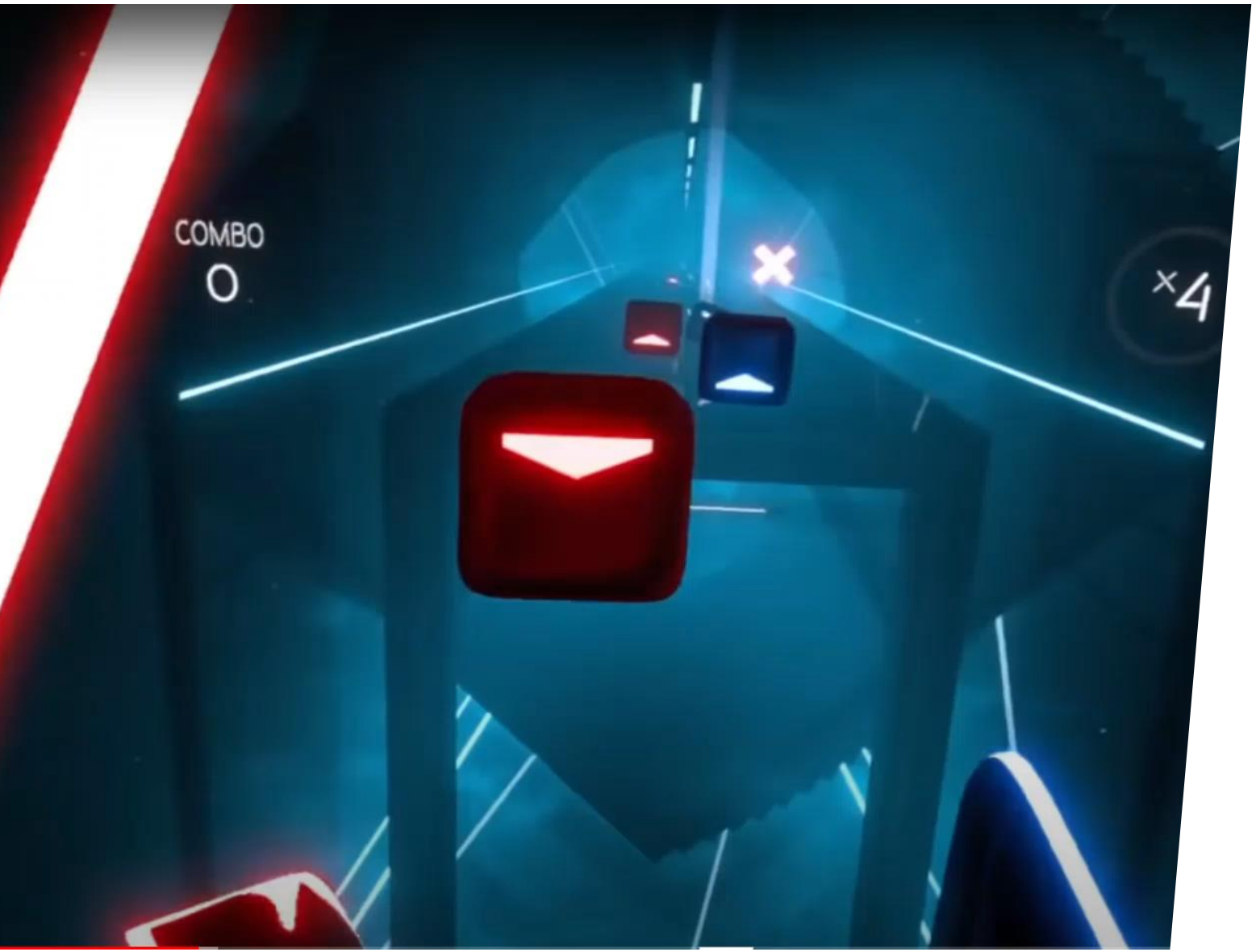
Functional Movement Systems[1], Ross 2005[2], Verschueren 2019[3], Maricot 2024[4], Ross 2008[5], VALD 2024[6]

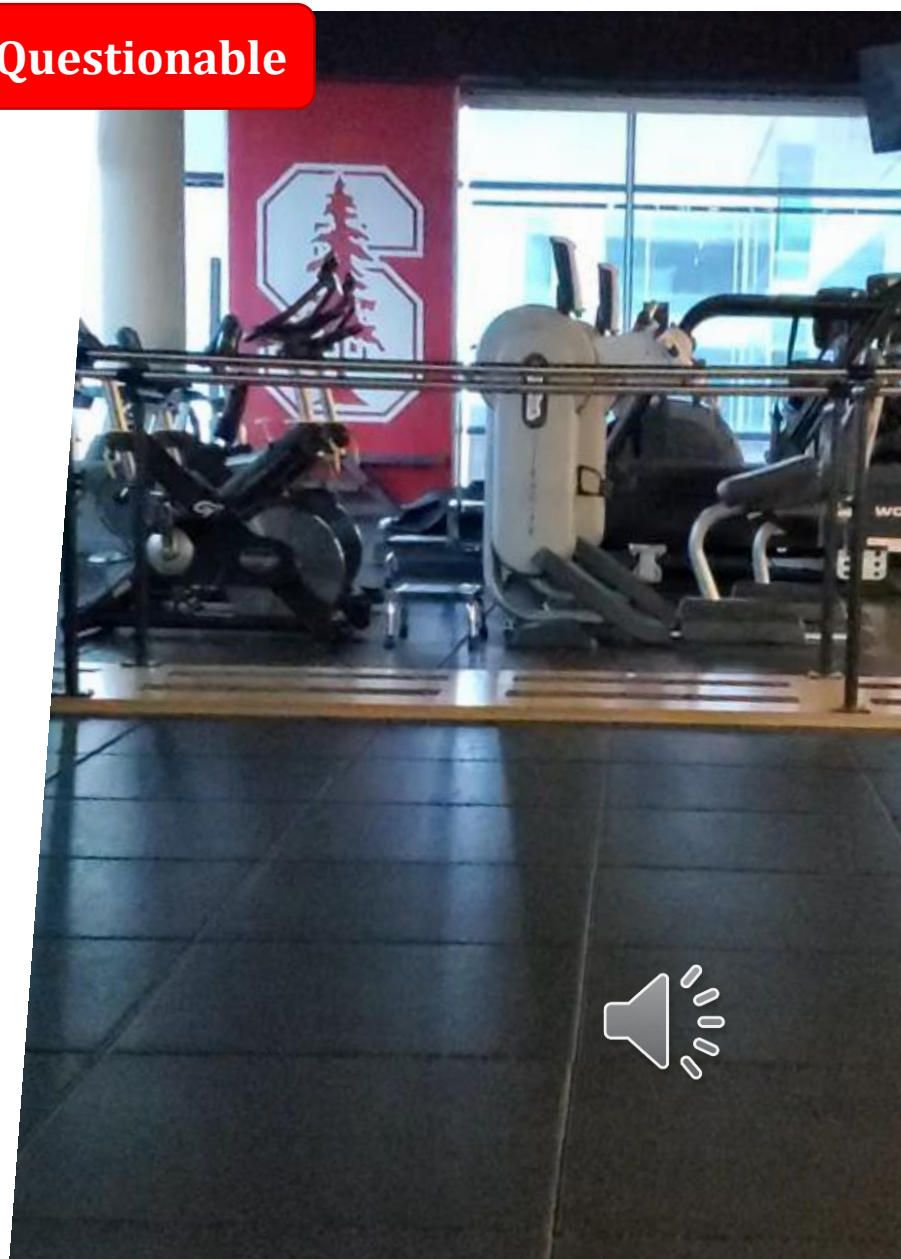
Postural Control Assessment

Level 4*†

Stable Surface Dynamic Feedback Balance

Questionable

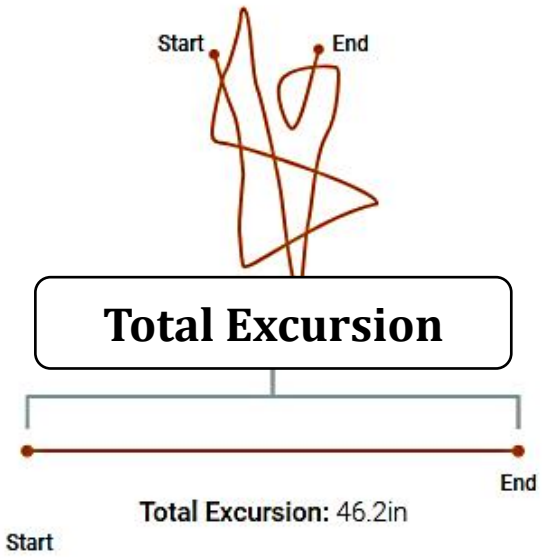


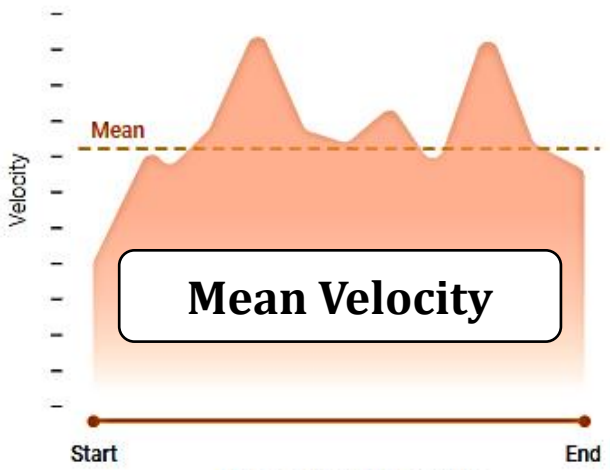


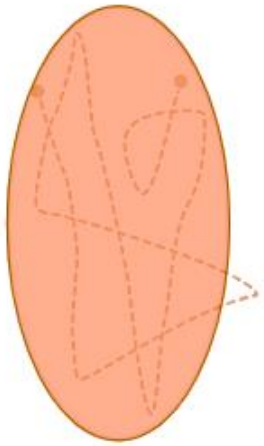
Postural Control Assessment

Level 4*†

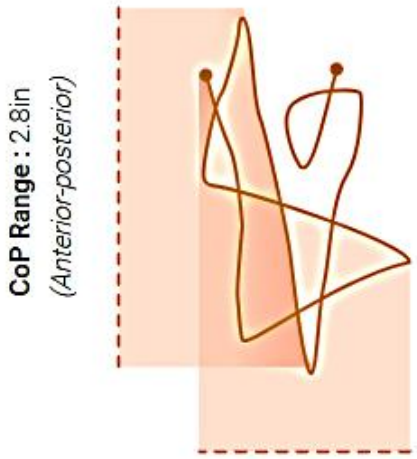
Stable Surface Dynamic Feedback Balance





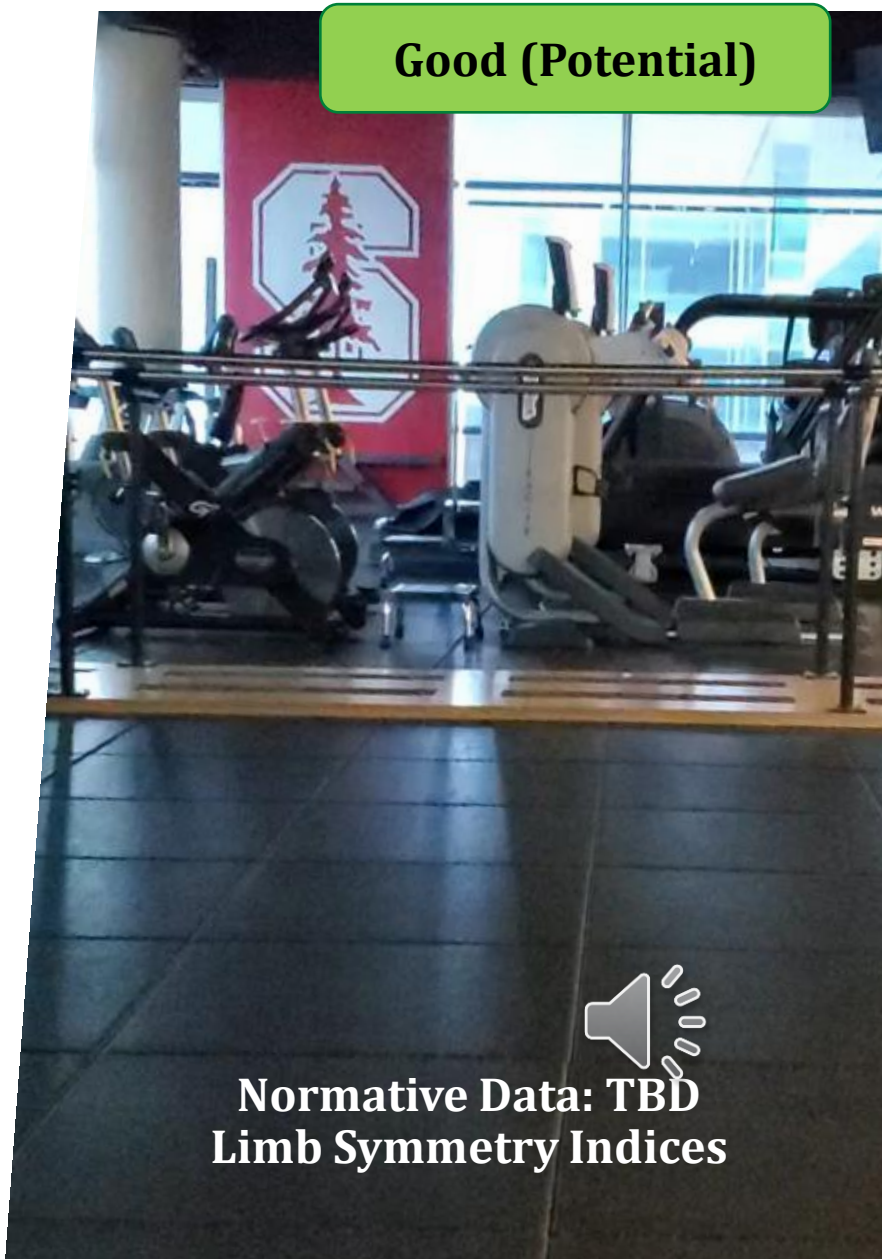


Area of Ellipse



Center of Pressure Range

Good (Potential)



Normative Data: TBD
Limb Symmetry Indices

Postural Control Assessments

Level 5*¥†
Single Limb Ballistic Dynamic Balance

Square Hop Test

Duration: 30 sec
Outcome:# of lines crossed or time (5 rounds)

Total = (# of rev's x 8) + (# of additional lines) - (# of lines hit)

Norms[2]
(*dominant/non-dominant)*
Males: 73 / 72
Females: 64 / 62

Group[2]	Square Hop
FAI-GW (FAI Limb)	18.7 ± 1.2 s
FAI-GW (Healthy Limb)	16.3 ± 0.6 s
FAI-NGW (FAI Limb)	14.8 ± 1.0 s
FAI-NGW (Healthy Leg)	14.7 ± 0.5 s
Control (Matched Leg)	15.3 ± 0.7 s

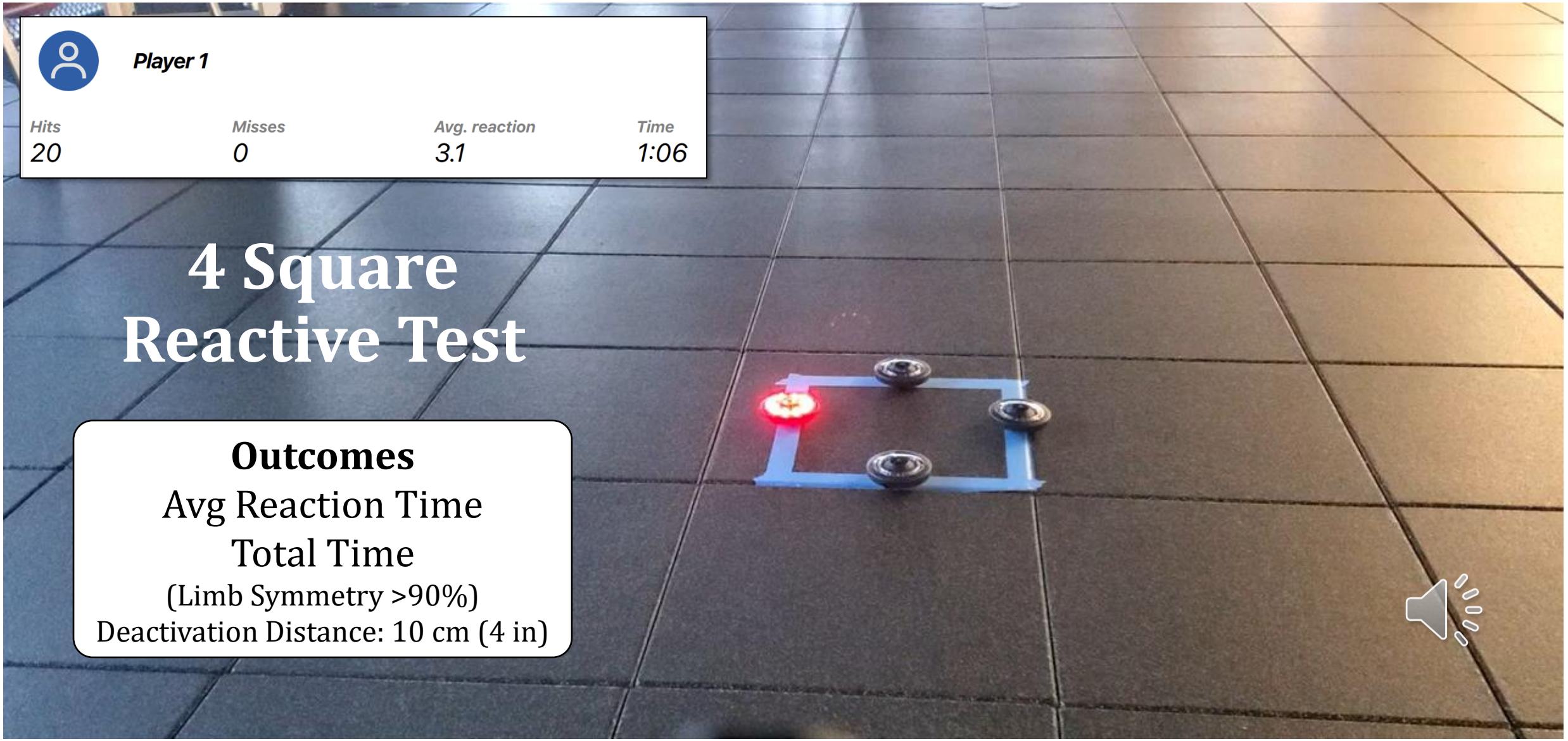
Reliability (ICC) [2]	0.90
Std Error of Measure[2]	**1.40 sec**
Min Detectable Change[2]	**3.88 sec**

Haitz et al 2014[1], Caffrey 2009[2]

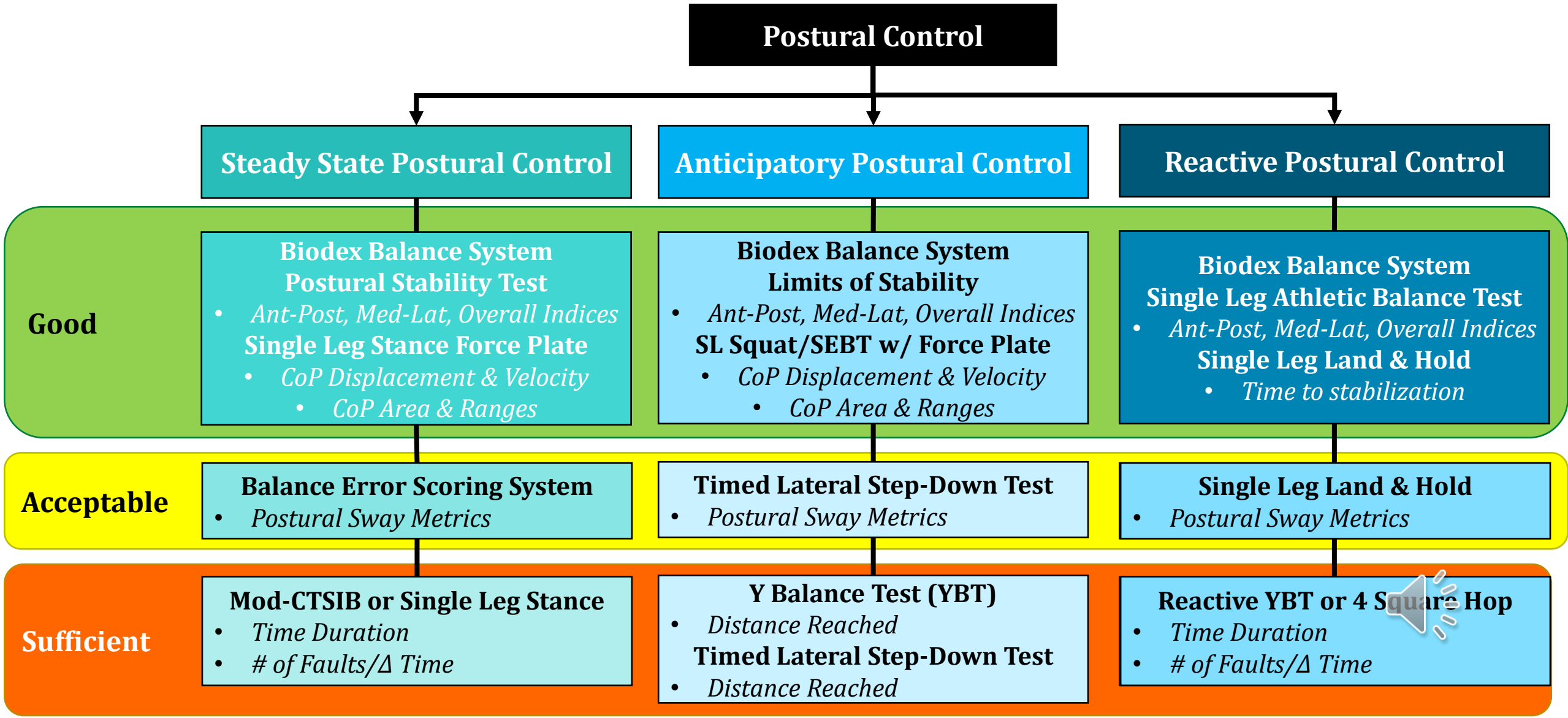
Postural Control Assessments

Sufficient

Level 5*¥†
Single Limb Ballistic Dynamic Balance



Postural Control: Constructs



Shunway & Cook 2014[1]

Postural Control Assessment Progression

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Level 2*†

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Level 3¥

Stable Surface Dynamic Feedforward Balance

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Single Limb Ballistic Dynamic Balance

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Shunway-Cook 2017