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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Learning Objectives

After attending this educational session, participants will be able to:

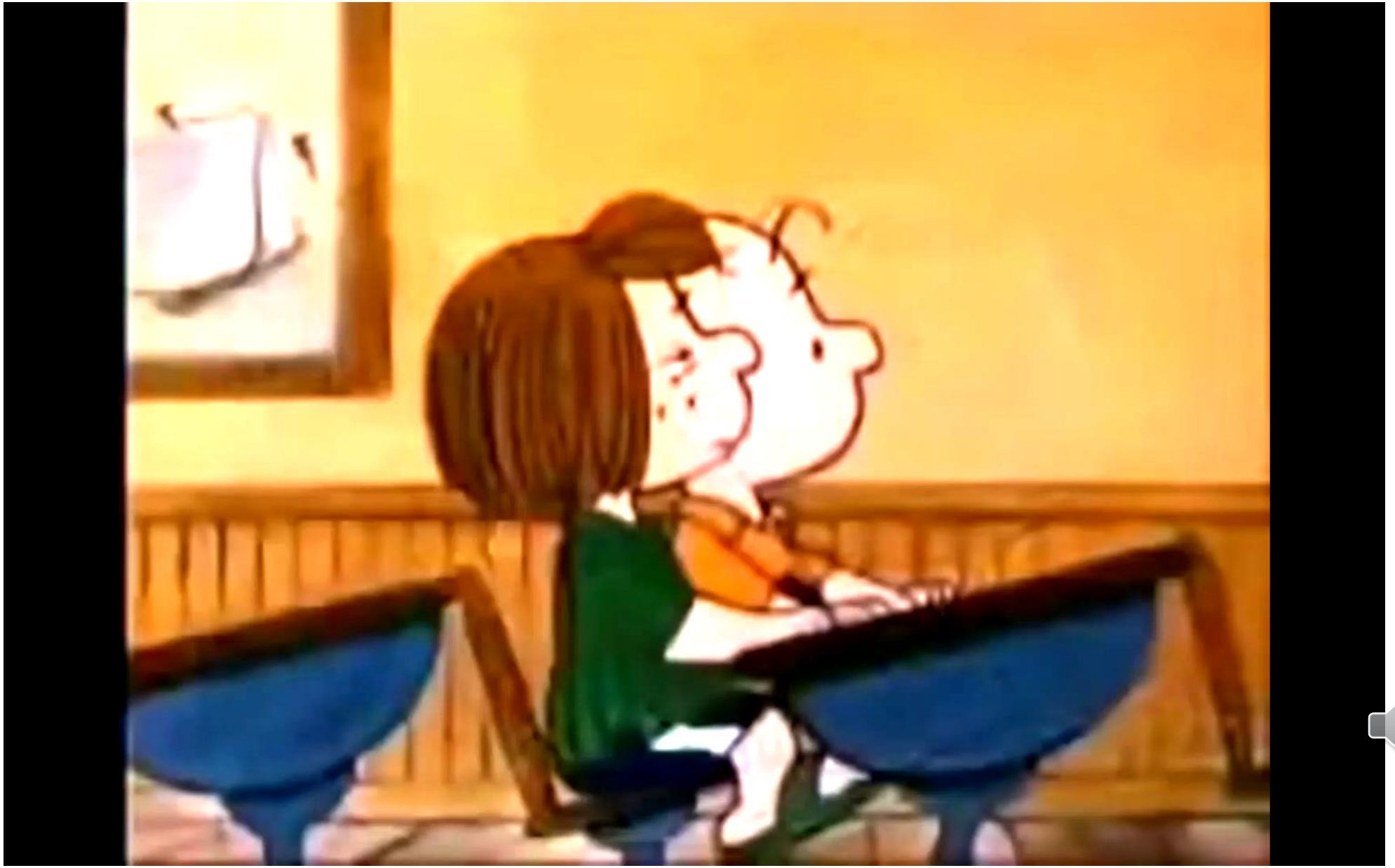
1. Analyze the importance of functional testing algorithms for determining return to function readiness in patients with foot and ankle musculoskeletal injuries.
2. Evaluate the evidence on the appropriate use of physical performance tests (PPTs) to determine readiness for return to function post foot and ankle musculoskeletal injury.
3. Develop a criterion, algorithmic, and evidence based approach of determining patient readiness and clearance for return to jogging, plyometrics, and higher-level activities.
4. Synthesize practical recommendations for implementing the Return to Function Physical Performance Testing Algorithm for the Foot and Ankle Complex in clinical practice, taking into account the patient's demographic, functional capacity, and specific pathology.

Session Outline

1. Introduction
   - Overview & epidemiology of foot & ankle injuries
2. Proposed Criteria for Clinical Milestones & Return to Activity Decision-Making
3. Early-Stage Criteria
   - Tissue Healing Timelines
   - Joint Pain & Symptoms
   - Patient Reported Outcomes
   - Joint Range of Motion
   - Neuromuscular Re-training
4. Mid-Stage Criteria
   - Range of Motion
   - Postural Control
   - Muscle Performance & Capacity
5. Force & Impact Absorption Capacity
   - Low-Level Plyometric
   - Return to Running Decision Making
6. Functional Full Kinetic Chain Re-Integration
   - Jump & Hop Tests
   - Multi-directional Hopping
7. Functional Testing Batteries
   - Proposed Physical Performance Batteries
8. Summary, Conclusion & Future Directions
   - Implications for Clinical Practice
   - Putting it all together: Key Takeaways
   - Practice Based Evidence: Implementation strategies and best practices
9. Discussion & Questions/Answers

Purpose...

Secondary Goal. Is to avoid this...



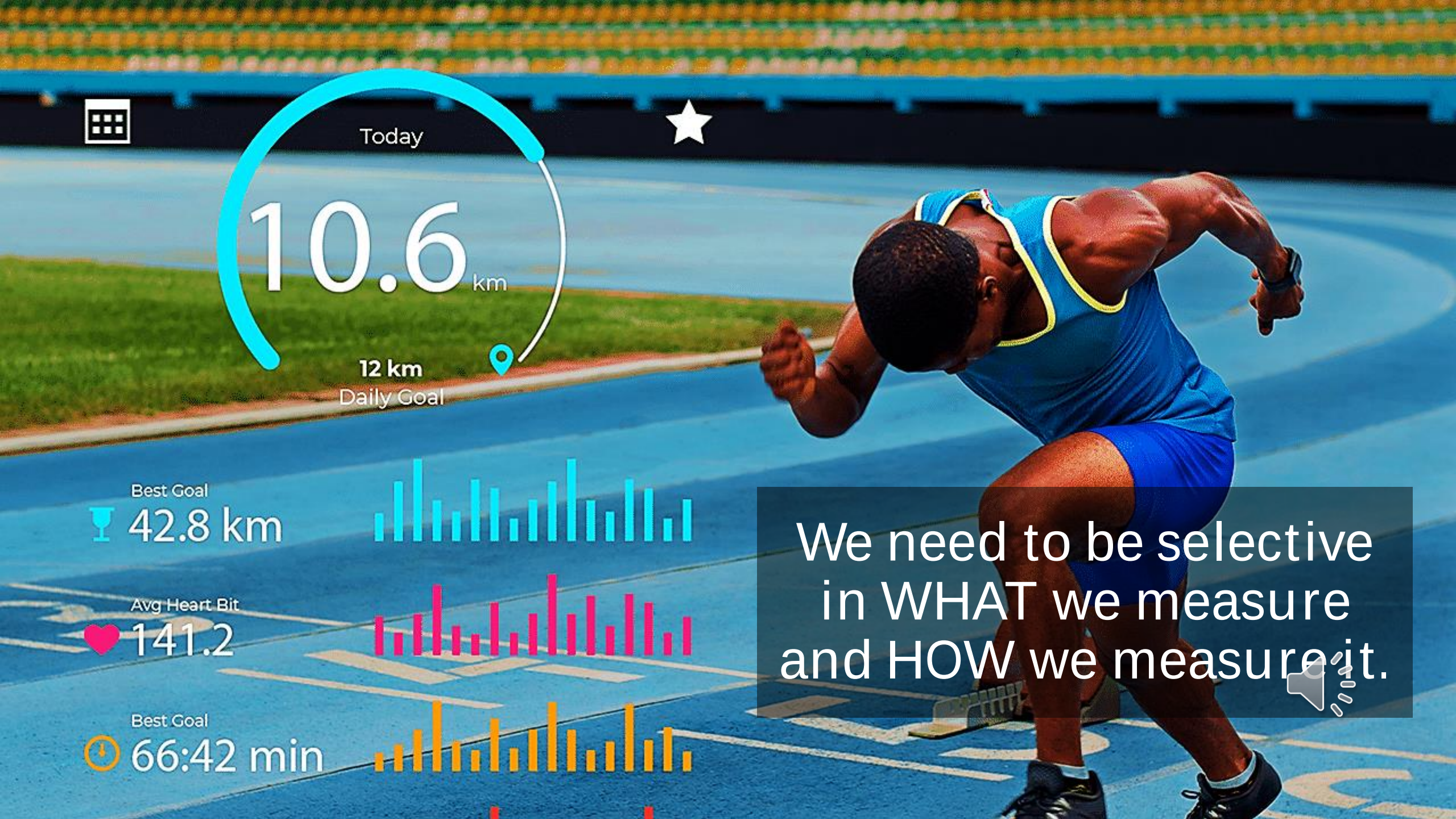
Presentation Road Map

- Speed Development
- Explosive & Elastic Strength
- Strength & Work Capacity
- Muscle Re-education
- Postural Control
- Mobility / Movement
- Tissue Protection

PART 3

PART 2

PART 1


Today
10.6 km
12 km
Daily Goal
Best Goal
42.8 km
Avg Heart Bit
141.2
Best Goal
66:42 min
We need to be selective in WHAT we measure and HOW we measure it.

Not all Tests & Measures Are Created Equal

Return to Sport Criteria

Dorsiflexion Passive Range of Motion: >40°

How is that measured?

What goes into a measurement?

1. *Reliability (consistency over time, providers, and clients)*
2. *Validity (accuracy (at least correlation) to gold standard)*
3. *Standard Error of Measure*
4. *Minimal Detectable Change*
5. *Normative Data (Interpretation)*

Not all Tests & Measures Are Created Equal

Do you know what Physical Quality the test measures?

YES

Do you know/understand what Outcomes Measures you will use?

YES

Does the test have sufficient Construct Validity & Reliability?

YES

Do you know how to Run the Test & Interpret the Results?

YES

Can you do at least two of the following:
Monitor, Prescribe, Rank
From the testing data?

YES

Use The Test

If NO...

Don't Use The Test

Educate Yourself

Measure What Matters.

"What gets measured gets managed."

Dysfunctional Consequences of Performance Measurements

V.F. Ridgway 1956
Admin Sci Quarterly

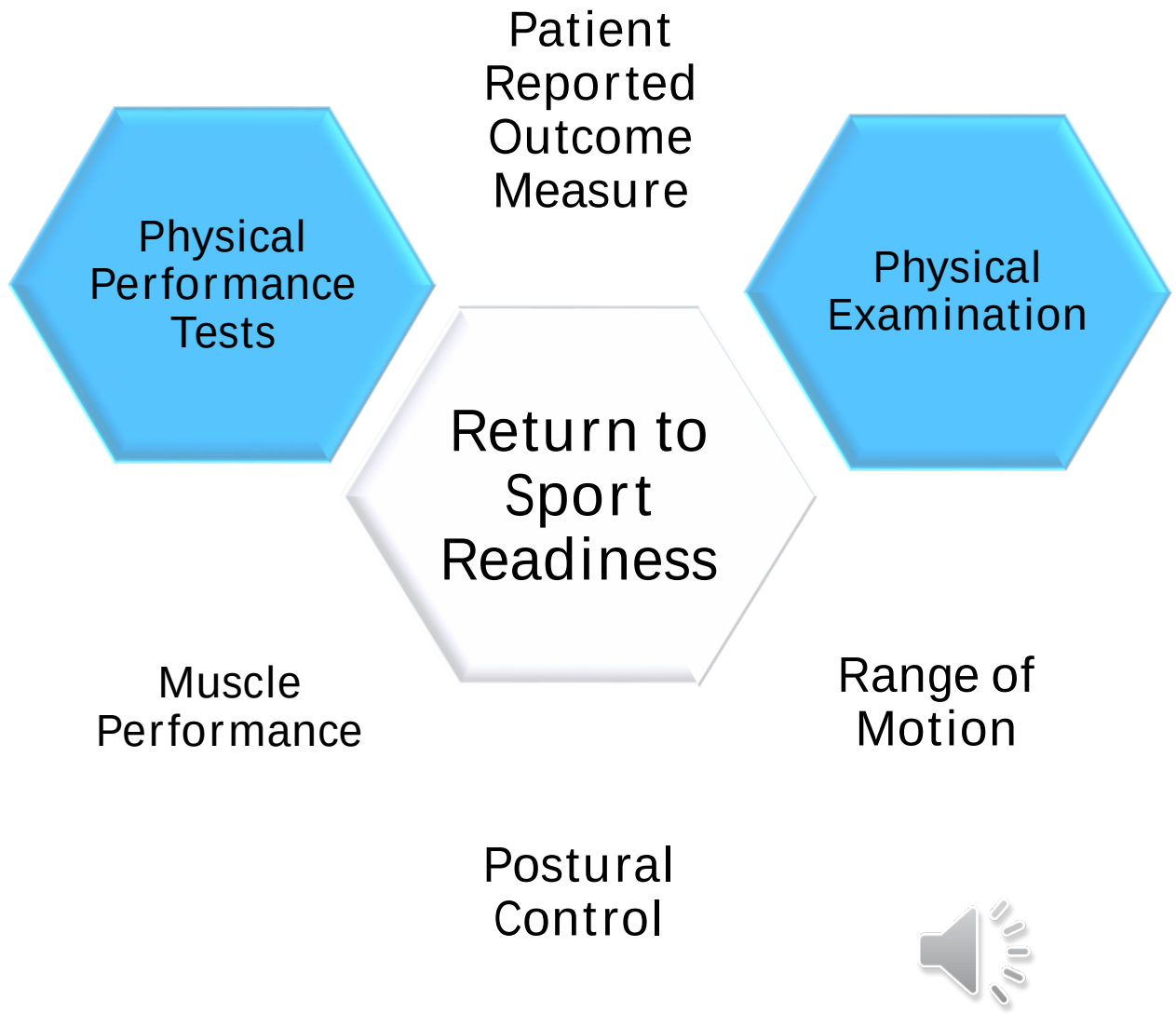
"What gets measured gets managed – *even when* it's pointless to measure AND manage it, AND *even if* it harms the purpose of the [provider] to do so"

– *Simon Caulkin summarizing*

V.F. Ridgway' s argument

Measure What Matters.

1. Understand Context & Objective
   - Understand:
     - specific physical demands of the patient/athlete
     - relative importance of KPIs to those demands
   - Identify predictable KPI deficits based on diagnosis/condition
2. Avoid Single-Criterion Measures
3. Use Multiple Criteria Judiciously
   - Employ multiple performance metrics that capture all critical aspects of the condition & physical demand
4. Develop Composite Measures with Clear Weight
5. Regularly Review & Adapt Metrics



Ankle & Foot Range of Motion

Foot & Ankle Range of Motion Pro Tips

When using a goniometer to measure foot/ankle (ROM), avoid the most common errors by:

❑ Proper positioning of the patient & goniometer

- *Ensure that the patient is in a consistent & relaxed position (seated or supine w/ foot supported)*

❑ Ensure accurate alignment of the goniometer with the anatomical landmarks *(e.g., the proximal phalanx and the metatarsal) can lead to inaccurate readings .*

❑ Failure to isolate the motion at the MTP joint

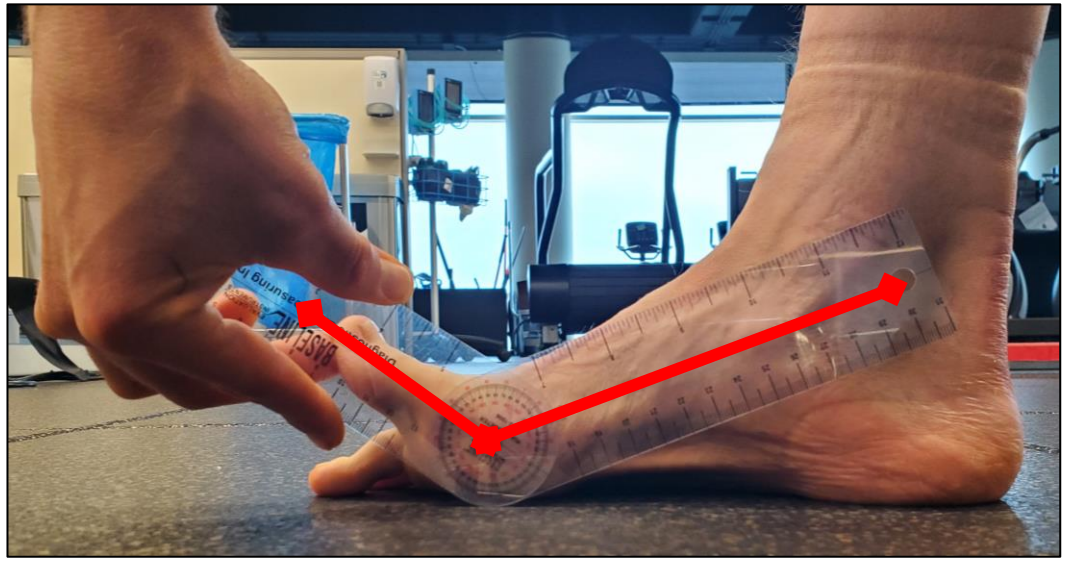
- *Unintentional movement of other joints, such as the ankle or midfoot, can influence the measurement.*
- *Stabilize the foot (or ankle) to ensure only the joint of interest is assessed*

❑ Inconsistency in measurement technique

- *Using different protocols or modifying measurement techniques between sessions can lead to errors.*

❑ Not accounting for patient comfort or pathology

- *E.g., hallux rigidus or pain, the range of motion might be limited by patient discomfort.*



Note. Clinical measurements with a goniometer typically underestimate hallux dorsiflexion (vs radiographic measurements). Thus, clinicians should understand that goniometric assessments may yield lower ROM values and interpret them accordingly.

By avoiding these errors and employing consistent, standardized techniques, clinicians can improve the accuracy of hallux (& other foot/ankle) ROM measurements.

Vulcano 2016

Ankle Range of Motion: Measure What Matters

Are clinical measures of foot posture and mobility associated with foot kinematics when walking? Buldt *et al*. (2015)

Results

- Degree of variance in peak & ROM kinematic variables were independently explained by:
  - Foot Posture Index-6: 5 – 22%*
  - Arch Index: 6 – 20%
  - Normalized Navicular Height: 7 – 13%
  - Normalized Dorsal Arch Height: 6 – 8%
  - Foot Mobility Magnitude Measure: 8%

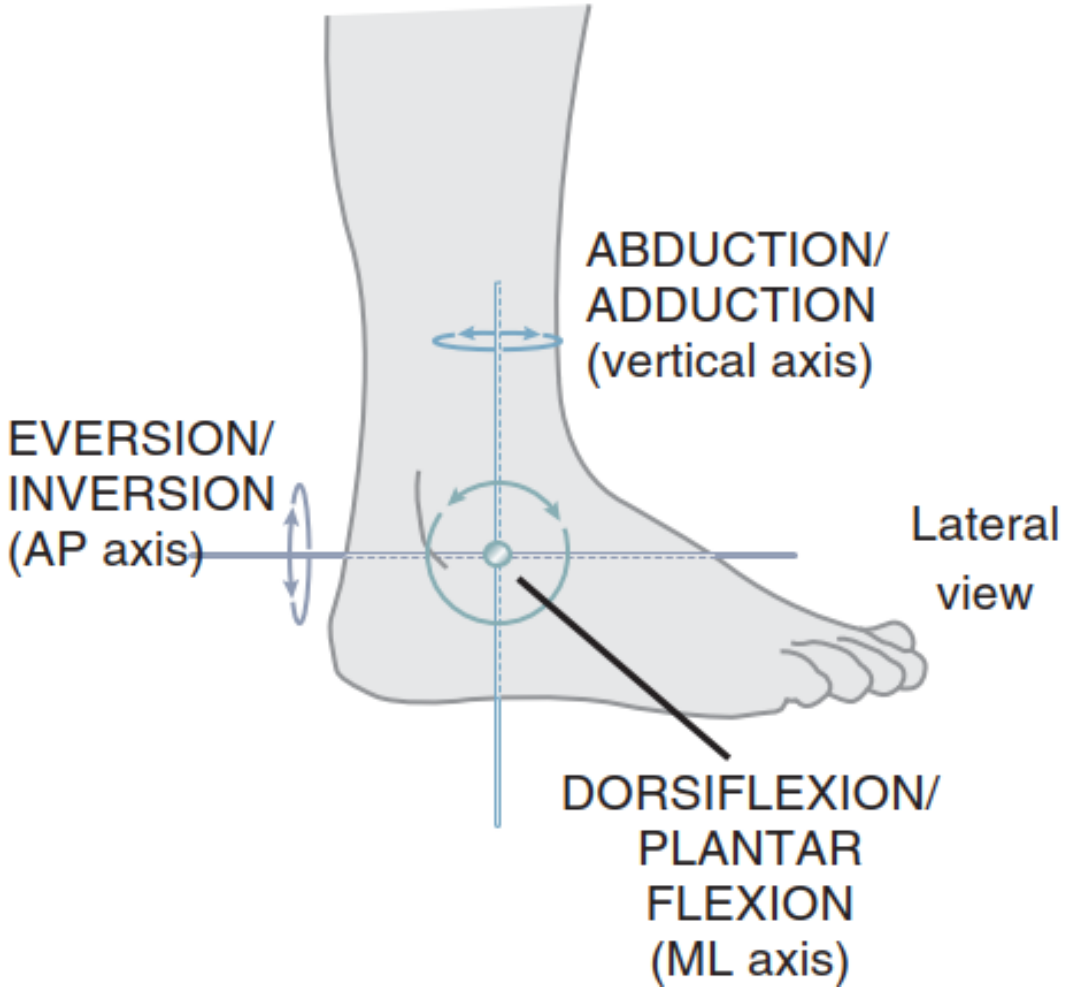
**significant predictor across the greatest number of kinematic variables*

Conclusions

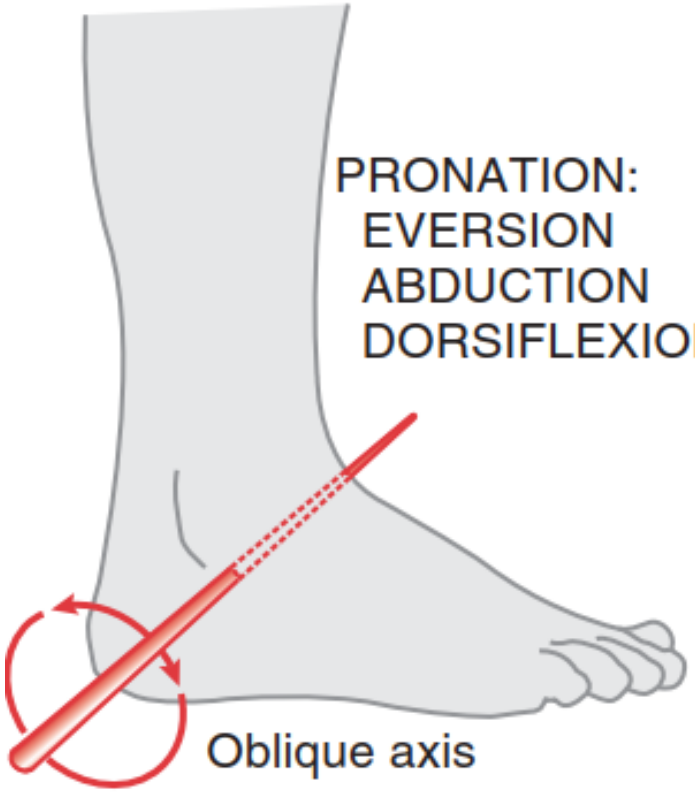
- Foot posture measures can explain only a ***small amount*** of variation in foot kinematics.
- Particular the FPI, were more strongly associated with foot kinematics *vs* foot mobility measures.
- These findings suggest that foot kinematics *cannot* be accurately inferred from clinical observations of foot posture alone.

Ankle Range of Motion

Fundamental Movement



Applied Movement



PRONATION:
EVERSION
ABDUCTION
DORSIFLEXION

SUPINATION:
INVERSION
ADDUCTION
PLANTAR FLEXION

Neuman 2016

Foot & Ankle Range of Motion

Open Kinetic Chain

Forefoot
- Hallux ROM
- 1st Ray
- Forefoot

Midfoot
- Cuboid
- Navicular
- FF Locking

Rearfoot
- Inv/Eversion
- Plantar Flexion
- DF Knee Extended
- DF Knee Flexed
- Achilles Resting Angle

Supine

Prone

Closed Kinetic Chain

Forefoot
- Hallux A/PROM
- *Forefoot**

Midfoot
- MLAA
- *Navicular Hgt**

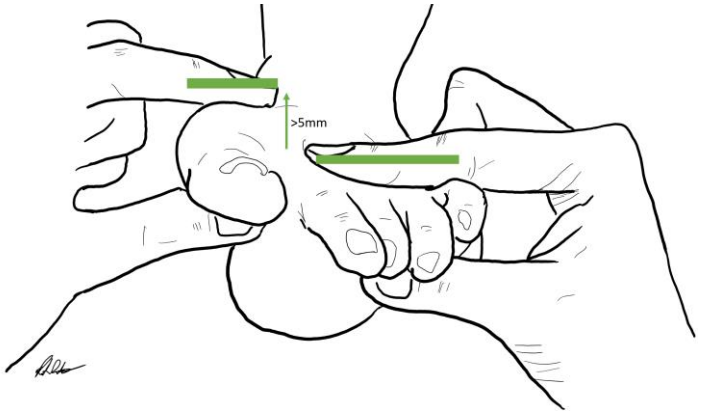
Rearfoot
- Plantar Flexion
- DF Knee Extended
- DF Knee Flexed
- *Inv/Eversion**

**Assessed dynamically with movement*

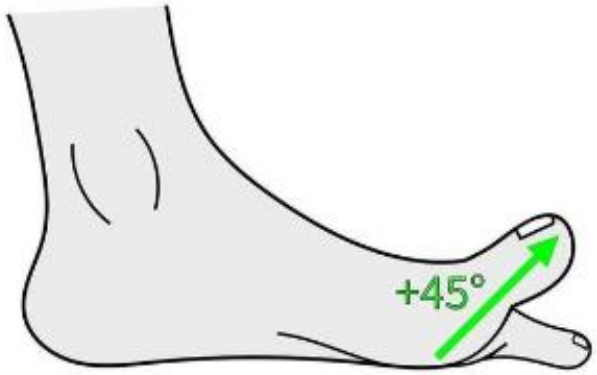
Foot Range of Motion (Open Kinetic Chain)

		Motion	Measurement Method/Tool	Criteria	Comparison Criteria
Supine	Forefoot	First Ray (TMT) DF/PF	Manual/Modified Ruler	Plantar Flexion: 5 mm[1] Dorsiflexion: 5 mm[1]	90% LSI &/or 90% of expected for condition/surgery
		Hallux Extension/Flexion	Electronic Goni/Phone*	MTP Extension 70°[3,6] MTP Flexion 45°[3,6]	
		Inversion/Eversion (Supination/Pronation)	Electronic Goni/Phone*	Inversion/Supination: 45-60°[6,8] Eversion/Pronation:15-30°[3,6,8]	
		Accessory Mobility	Manual	*Clinician Expertise*[3]	

Note. *, traditional goniometer acceptable



Inter-Rater Reliability: 0.42-0.53[9]
Test-Retest Reliability: 0.62- 0.90[9]



Inter-Rater Reliability: 0.88-0.91[9]
Test-Retest Reliability: 0.82-0.93[9]

Inter-Rater Reliability: 0.66- 0.83[9]
Test-Retest Reliability: 0.72- 0.86[9]
SEM: 1.54-1.95°[10] | MDC: 4.26-5.4°[10]

Munuera-Martínez 2020[1], Khuc 2023[2], Magee & Manske 2021[3], Cook 2010[4], Carmont 2014[5], Dutton 2012[6], Reese 2016[7], Ellis 2006[8] , Fraser 2006[9] , Magalhães 2020[10]

Foot Range of Motion: First Ray Mobility

Clinical Significance

- First Ray Hypomobility risk factor for:[1]
  - Hallux valgus
  - Central metatarsal stress fractures
  - Metatarsal arthralgia
  - Hammer Toes
  - Acquired flat foot deformities
  - Tibialis Posterior Dysfunction
- Keystone of the medial longitudinal arch[3]
- Execution of functional movements[4]
- Even mild hallux dysfunction has been associated with impaired walking mobility, balance, postural stability deficits, and fear of falling.[2]

Glasoe & Michaud 2019[1], Oztarsu & Oksuz 2023[2], Mickle 2009[3], Mickle *et al* 2016[4]

Foot & Ankle Range of Motion

Open Kinetic Chain

Forefoot
- Hallux ROM
- 1st Ray
- Forefoot

Midfoot
- Cuboid
- Navicular
- FF Locking

Rearfoot
- Inv/Eversion
- Plantar Flexion
- DF Knee Extended
- DF Knee Flexed
- Achilles Resting Angle

Supine

Prone

Closed Kinetic Chain

Forefoot
- Hallux A/PROM
- *Forefoot**

Midfoot
- MLAA
- *Navicular Hgt**

Rearfoot
- Plantar Flexion
- DF Knee Extended
- DF Knee Flexed
- *Inv/Eversion**

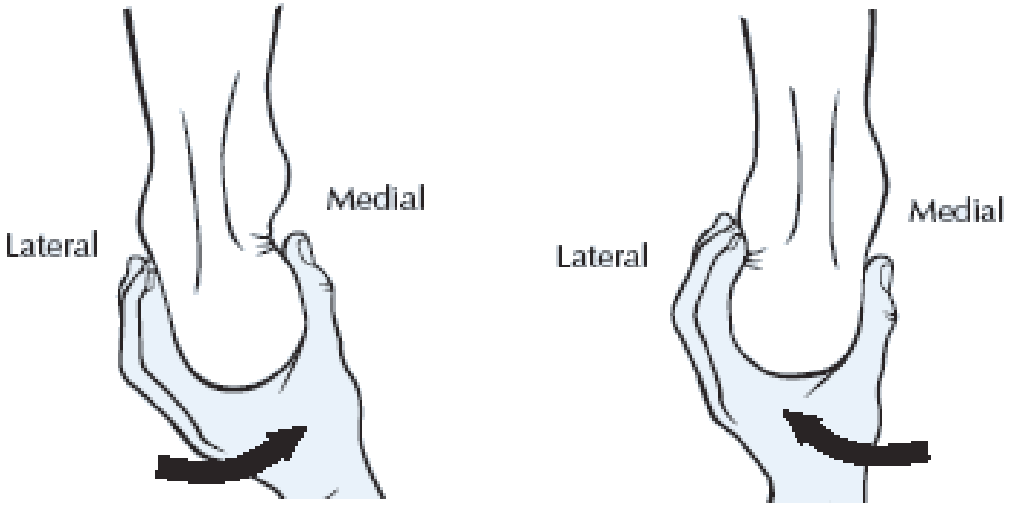
**Assessed dynamically with movement*

Ankle Range of Motion (Open Kinetic Chain)

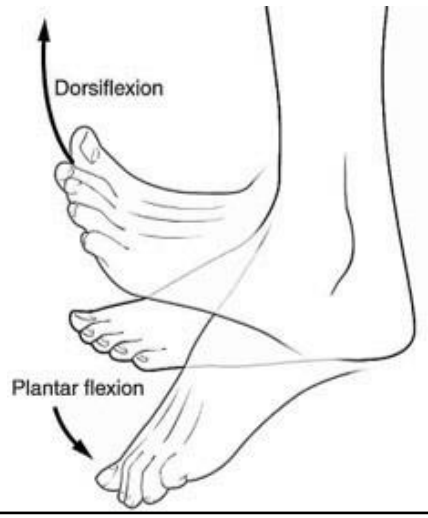
		Motion	Measurement Tool	Criteria	Comparison Criteria
Prone	Rearfoot	Inversion/Eversion	Goniometer	Inversion: 20°[3,6] | Eversion: 10°[3,6] 2:1 | Inv:Evr[3,6]	90% LSI &/or 90% of expected for condition/surgery
		Plantar Flexion	Electronic Goni/Phone*	50°[3] (40°-65°|MDC: 13°)[7]	
		Dorsiflexion (Knee Extended)	Electronic Goni/Phone*	>20°[3,4] (10°-25°|MDC: 3-8°)[677]	
		Achilles Tendon Resting Angle	Electronic Goni/Phone*	Uninjured: 43°±7°[5] |50°[8] (26°-61°)[8] Ruptured: 55°±8°|Repaired:37°±9°[5] (SEM: 2.4°)[8]	
		Dorsiflexion (Knee Flexed)	Electronic Goni/Phone*	≥30°[4]	

Note. *, traditional goniometer acceptable

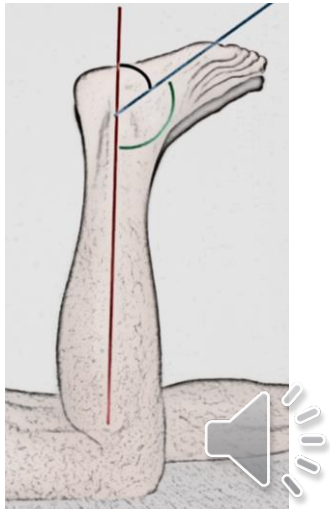
Magee 2021[3], Cook 2010[4], Carmont 2014[5], Dutton 2012[6], Reese 2016[7], Carmont 2013[8] , Fraser 2017[9]



Inter-Rater Reliability: 0.53-0.69[9]
Test-Retest Reliability: 0.58-0.73[9]



Inter-Rater Reliability: 0.76 -0.85[9]
Test-Retest Reliability: 0.81-0.88[9]



Test-Retest Reliability: 0.91[8]

Ankle Range of Motion: Dorsiflexion

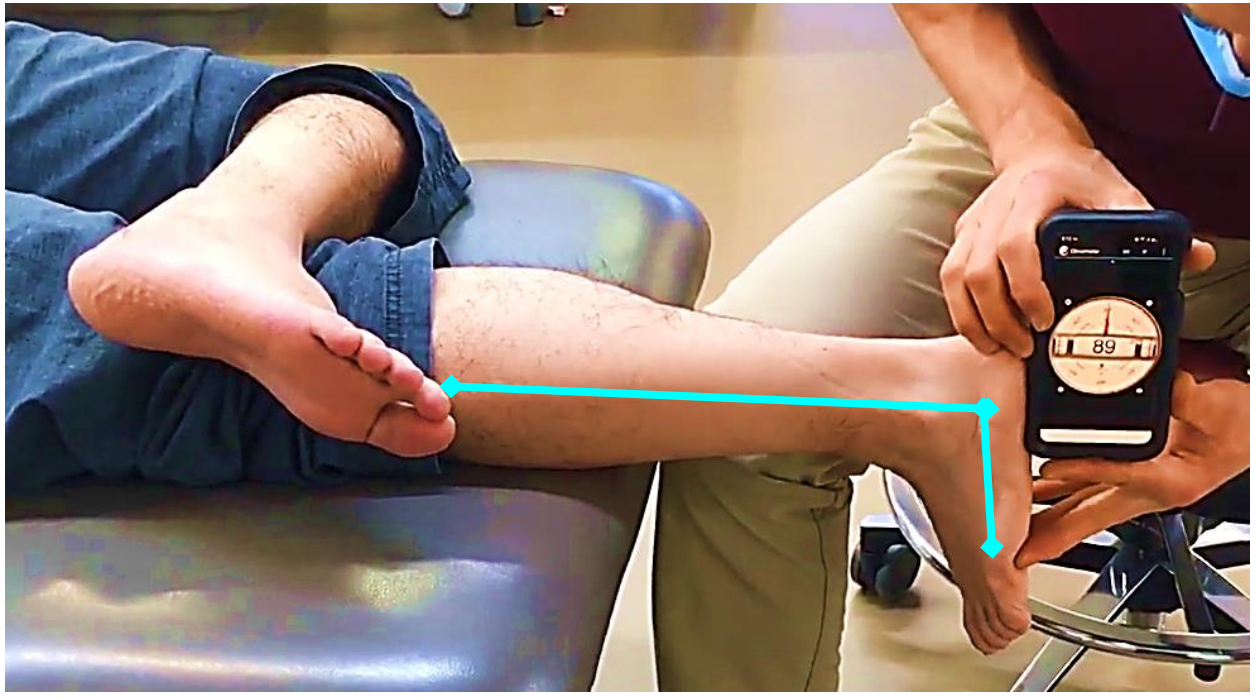
Clinical Significance

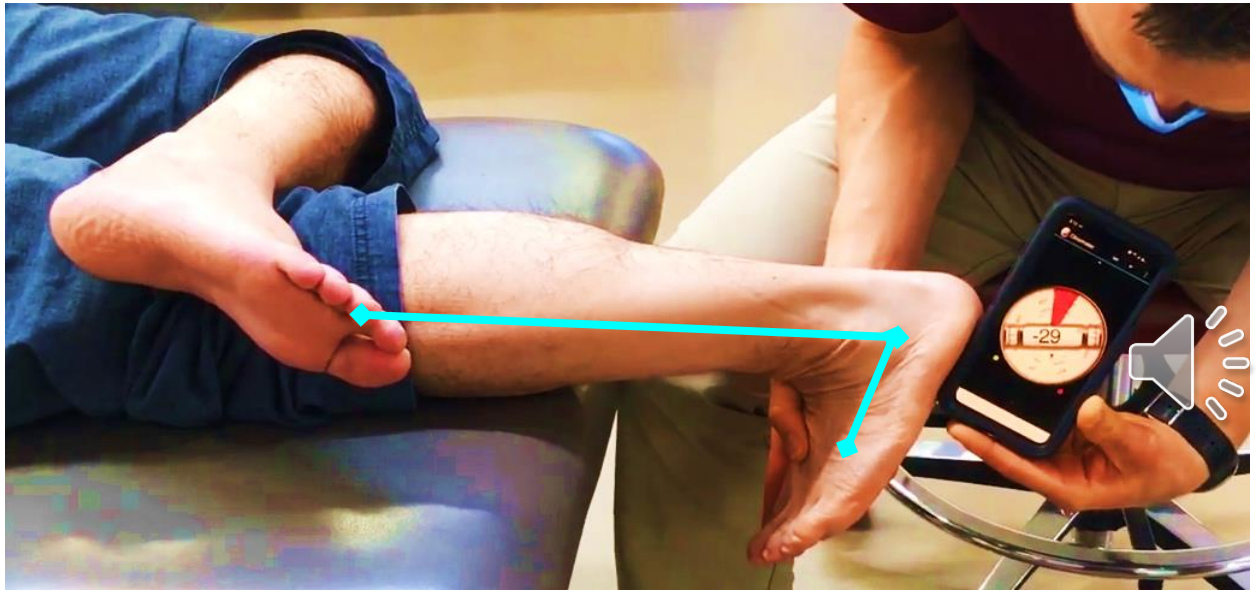
- ⬆ Ankle DF PROM was associated with ⬆ knee-flexion displacement & ⬇ GRF during landing, which may be associated with a ⬇ ACL loading & ⬇ risk of ACL injury.[1]
- Clinical measures of DF ROM may be helpful in identifying individuals at ⬆ risk of ACL injury.[1]
- ⬇DF ROM is associated with:
  - ⬆ Ankle & ⬆ overall lower extremity injury risk.[1-5]
  - Prior injury sequela.[1-5]
  - Varying degrees of altered kinematics & dynamics in the pelvis, hip, knee, and foot during walking and jogging.[6]
  - ⬇ the body's ability to propel forward in walking and jogging ➔ ⬇ Performance &⬆ Injury risk.[7]

Fong 2011[1], Plinksy 2021[2], Malliaras 2006[3], Rodney 1998[4], Belinda 2004[5], Rao 2023[6], Chun-Man 2011[7], Sommer & Vallentyne 1995[8]

Ankle Range of Motion: Dorsiflexion (Knee Ext)

- ☐ Patient Position
  - *Prone & Knee Extended (0°)*
  - *Opposite Leg: "figure 4 position"*
- ☐ Measurement Tool
  - *(Electronic) Goniometer*
  - *Phone flush along calcaneus*
- ☐ Start Ankle @ ~0° PF





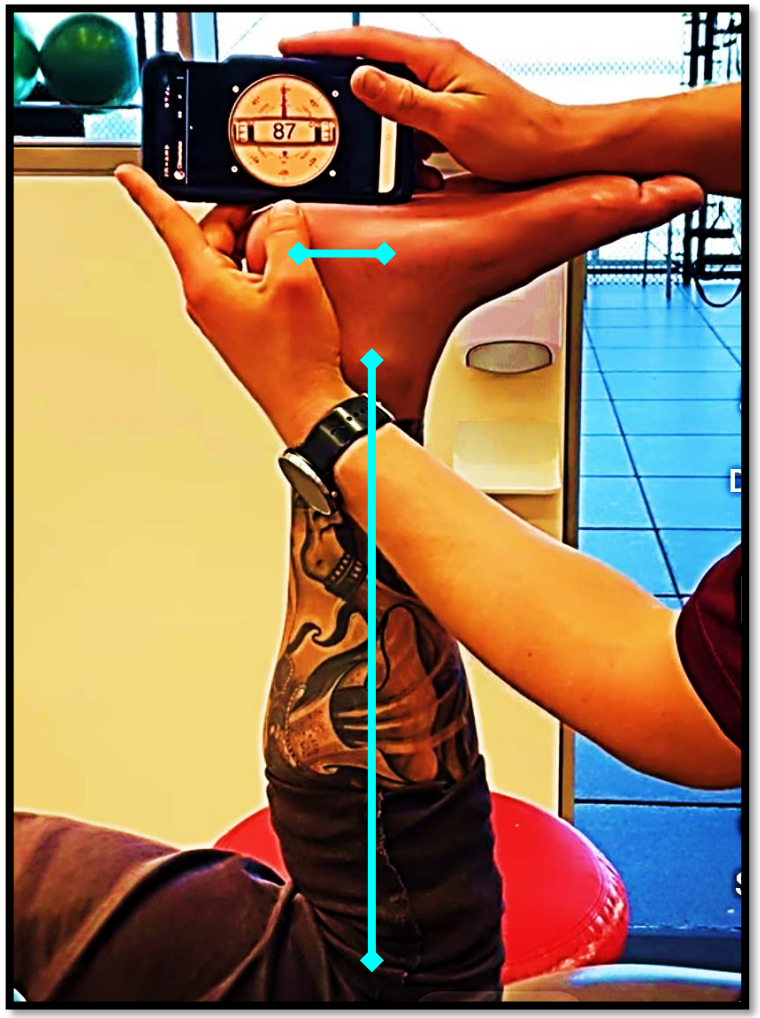
Inter-Rater Reliability: 0.76 -0.85[1,2]
Intra-Rater Reliability: 0.91[2]
Test-Retest Reliability: 0.81-0.88[1]

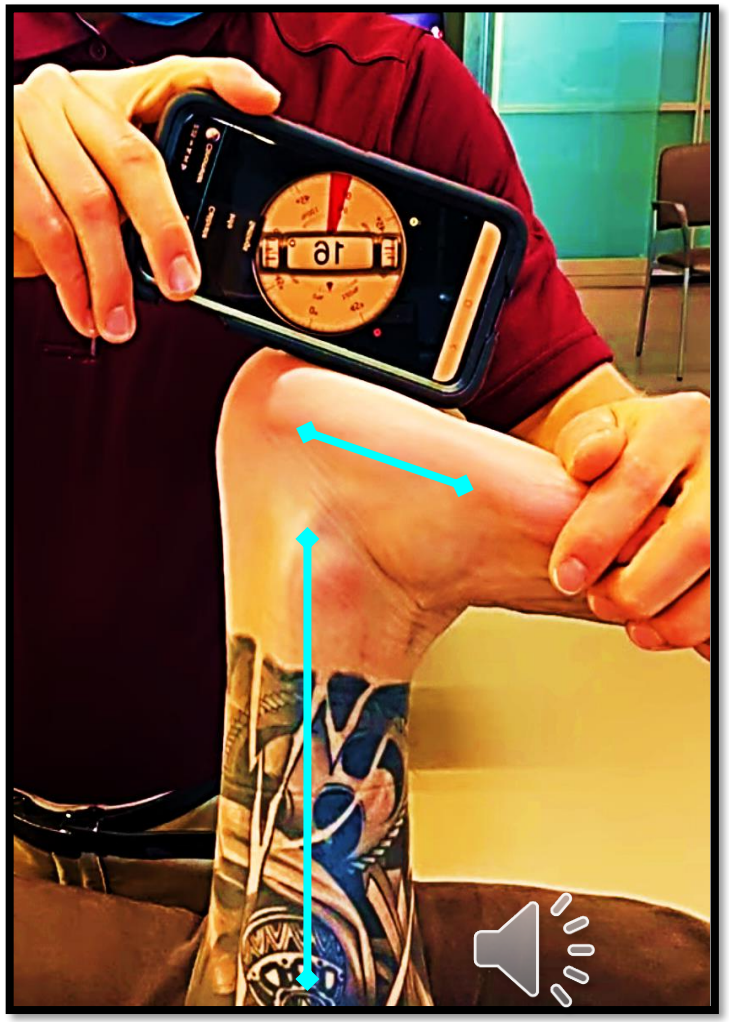
Fraser 2017[1] , Alawna[2]

Ankle Range of Motion: Dorsiflexion (Knee Flexed)

- ☐ Patient Position
  - *Prone & Knee Flexed to 90°*
  - *Standardize Vertical Tibial Position*
- ☐ Measurement Tool
  - *(Electronic) Goniometer*
  - *Phone flush along calcaneus*
- ☐ Start Ankle @ ~0° PF

Inter-Rater Reliability:
0.76 -0.85[1] | 0.82[2]
Intra-Rater Reliability:
0.91[2]
Test-Retest Reliability:
0.81-0.88[1]



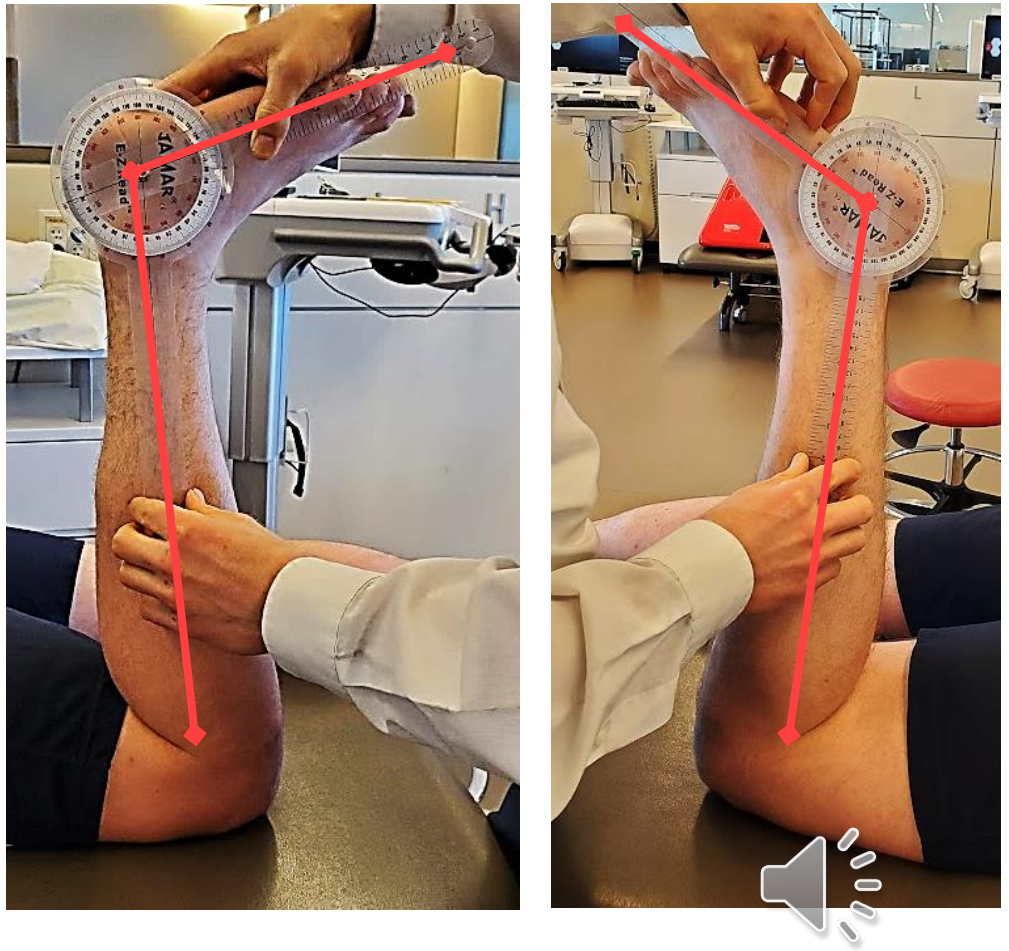


Fraser 2017[1] , Alawna 2019[2]

Ankle Range of Motion:
Achilles Tendon Resting Angle (ATRA)

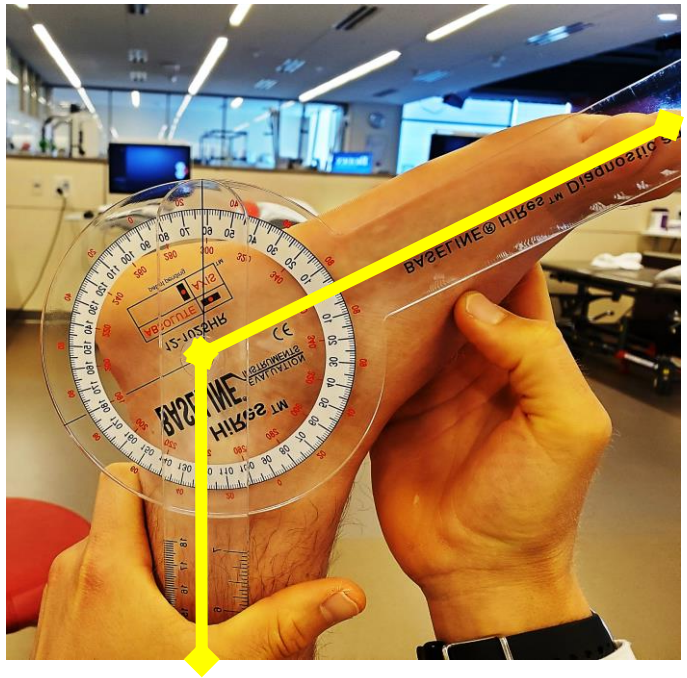
Clinical Significance

- *Achilles tendon elongation* post repair is associated with ⬇*heel height* and ⬇*total work* ($\rho = -.782$, $P = .008$) on single leg calf raise test.[2,3]
- ⬇ plantar flexion strength post Achilles tendon repair is associated with *lengthening of the tendon* during healing ($\rho = .608$, $P < .001$).[1,3]
- The ATRA has a strong association with ⬇ shear modulus ($\rho = .800$, $P = .01$) on ultrasound.[3]
- Tendon elongation ➡ in functional impairments:[3]
  - End range plantarflexion weakness
  - Changes in triceps surae activity
  - Altered running & jumping biomechanics
- ≥12° ⬆ in dorsiflexion angle change = ≥1 cm tendon elongation[2]
- ATRA is a quick measure that only requires a very inexpensive piece of equipment increasing its clinical utility.



Carmont *et al*. 2015[1], Carmont *et al* 2017[2], Zellers *et al* 2018[3], Mousavi *et al* 2019[4]

Ankle Range of Motion: Achilles Resting Angle



Inter-Rater Reliability
Achilles Tendon Resting Angle (ATRA): 0.84[1] - 0.91[2]

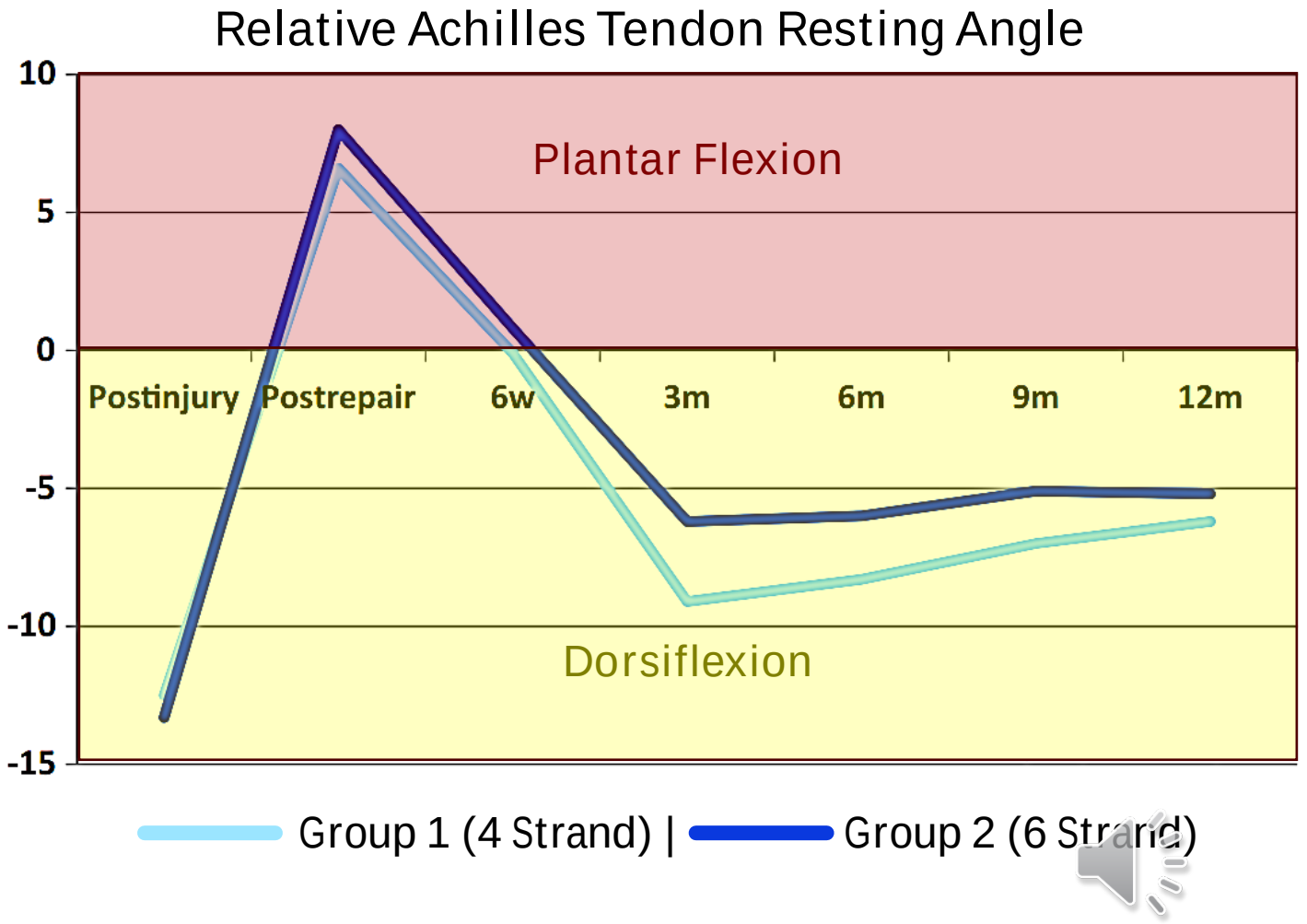
Standard Error of Measurement:
Achilles Tendon Resting Angle (ATRA): 1.5°[1]-2.5°[2] (2.4%[1])

Minimal Detectable Change:
Achilles Tendon Resting Angle (ATRA): 4.3°[1] (6.6%)[1]

Hansen *et al* 2017[1], Carmont *et al*. 2013[2], Zellers *et al* 2018[3], Mousavi *et al* 2019[4]

Ankle Range of Motion: Achilles Resting Angle

- ATRA across studies consistently demonstrates a *significant improvement immediately post operatively*.[1]
- The improvement in ATRA between 3 to 12 mo. suggests that ATRA changes are *not* associated with suture absorption[1]
- ATRA changes are associated:[1]
  - with *period of time mobilizing* after splint removal
  - *period of early WB & early mobilization*, suggesting reconsideration of the concept of early rehabilitation
  - Wedges alone do *not* prevent increments in ATRA



Carmont *et al* 2017[1]

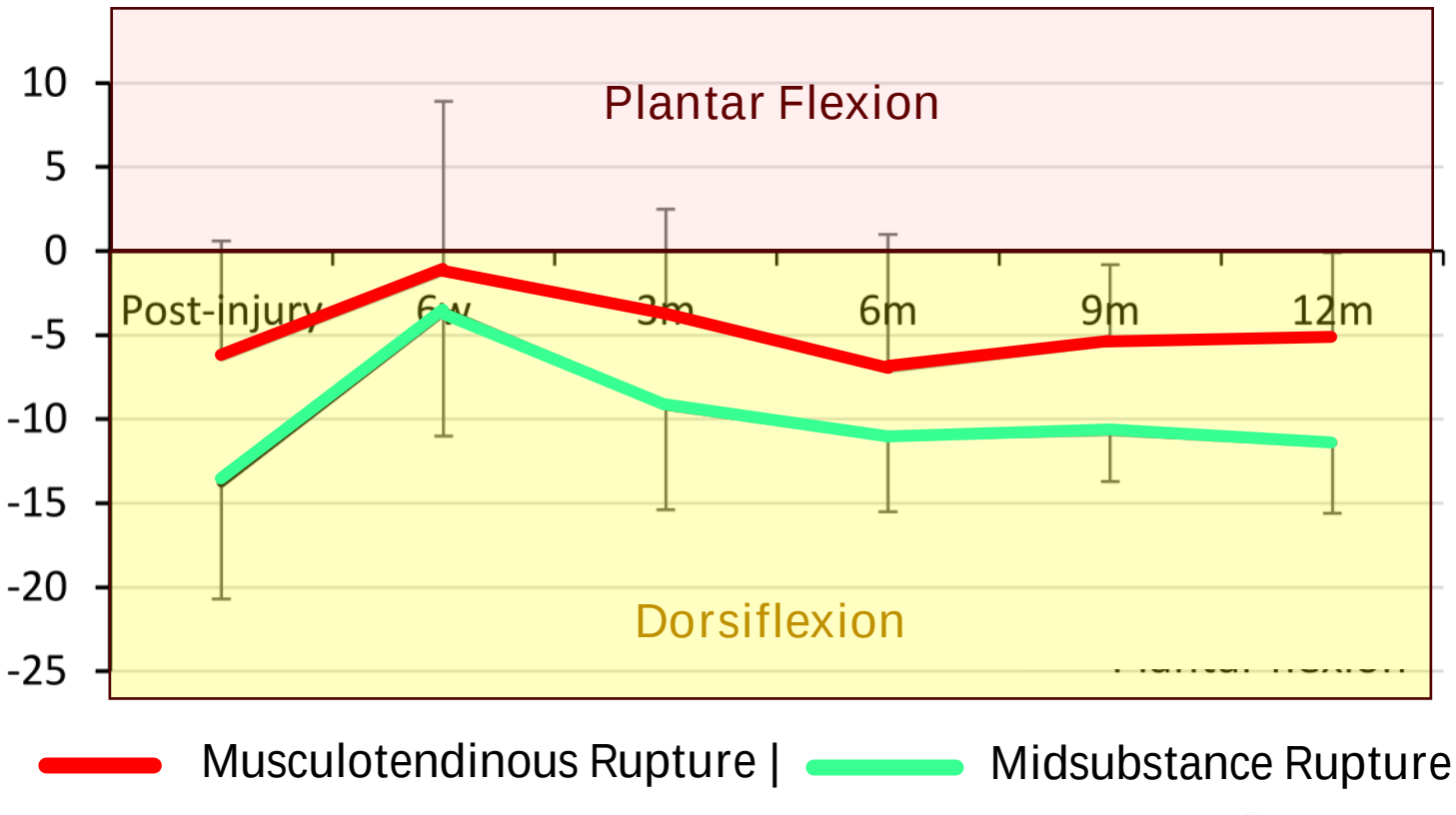
Ankle Range of Motion: Achilles Resting Angle

Achilles Tendon Ruptures Treated Non-operatively

Complications	MT Cohort	MS Cohort
Re-rupture	0%	8%
Tendon Elongation	0%	21%
Non-union	0%	4.2%
Adhesions	2.7%	0%
Deep Vein Thromb	2.7%	4.2%
Nerve Dysaesthesia	0%	12.5%

Note. MT, musculotendinous rupture; MS mid-substance rupture

Relative Achilles Tendon Resting Angle



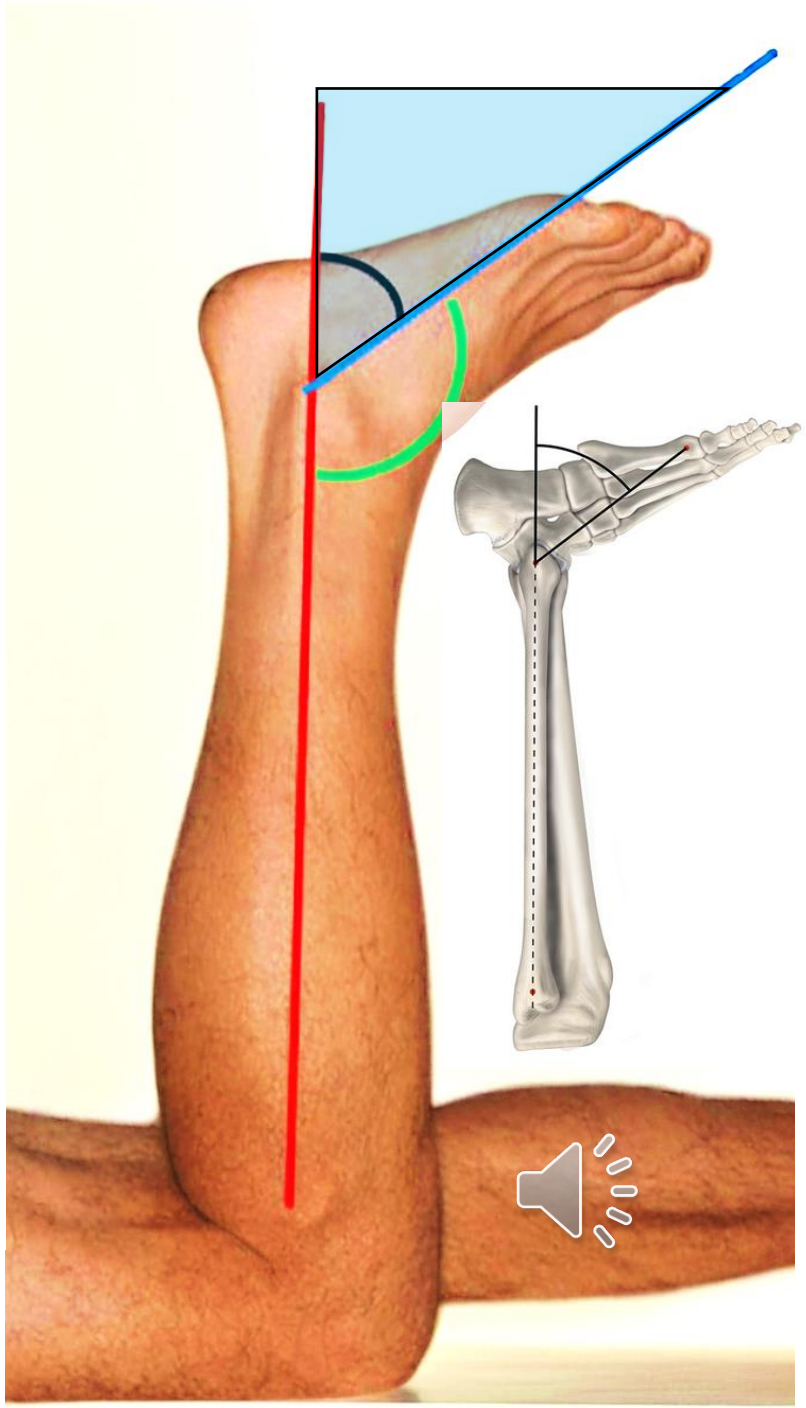
Patients with a MT ATR with 6 weeks period of brace protection, have little limitation, although have some residual reduction of single heel-rise at the one-year following injury

Carmont *et al* 2024[1]

Ankle Range of Motion: Achilles Tendon Resting Measurement

- ☐ Patient Position: *Prone & Knee Flexed 90°*
- ☐ Measurement Tool: *(electronic) goniometer*
- ☐ Foot & Ankle Passively Resting
- ☐ Angle Measurement:

Angle between long axis of fibula & line between malleoli & 5th metatarsal head



Note. *measured w. electronic goniometer along 5th metatarsal; NA, not applicable; wk, weeks; yr, year

Carmont 2015[1], Carmont 2013[2], Zellers 2018[3], Hürmeydan 2020[4], Hansen 2017[5]

Ankle Range of Motion: Plantarflexion (Knee Flexed)

- ☐ Patient Position: *Prone Knee Flexed 90°*
- ☐ Measurement Tool
  - *(Electronic) Goniometer*
  - *Phone flush along calcaneus*
- ☐ Start Ankle @ ~0° PF

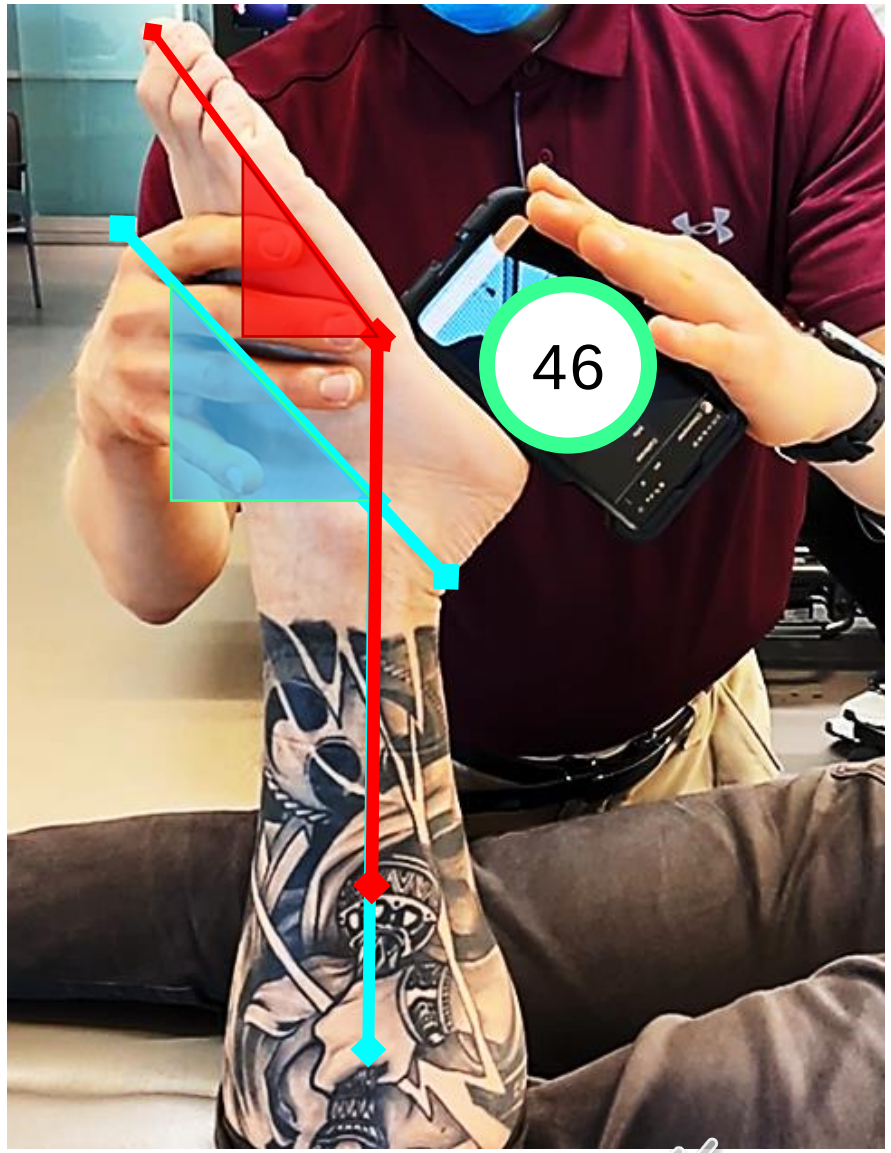
Inter-Rater Reliability:
0.76 -0.85[1] | 0.82[2]
Test-Retest Reliability:
0.81-0.88[1]

Position of Measurement Matters

Age Range	6-19	20-44	45-69
Female	57.3 (54.8–59.8)	62.1 (60.6–63.6)	56.5 (55.0–58.0)
Male	52.8 (50.8–54.8)	54.6 (53.2–56.0)	49.4 (47.7–51.1)

Note. Measurements of >1200 ankles taken in seated[3]

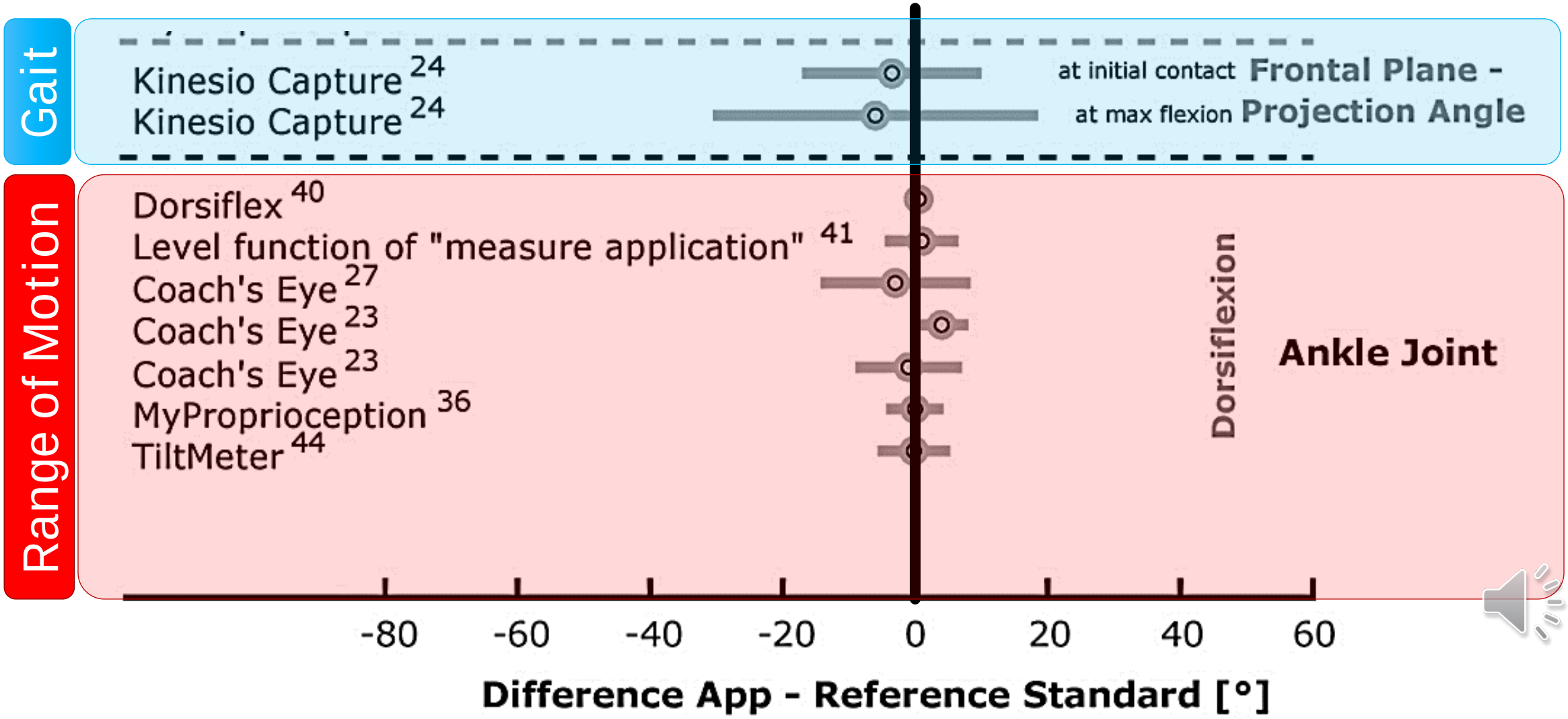
Fraser 2017[1] , Alawna[2] , Soucie 2011[3] , Stamm 2016[4]



Note. PF ROM varies from small (2°-8°) in low arches, moderate (3°-12°) in high arches, & large (2°-20°) in normal arches; suggesting that the rearfoot plantar flexion is influenced by the arch type and can vary significantly.[4]

Ankle Range of Motion: Leveraging Modern Technology

Reliability and validity varies among smartphone apps for range of motion measurements of the lower extremity: a systematic review Hahn 2021[1]



Foot & Ankle Range of Motion

Open Kinetic Chain

Forefoot
- Hallux
- 1st Ray
- Forefoot

Midfoot
- Cuboid
- Navicular
- FF Locking

Rearfoot
- Inv/Eversion
- Plantar Flexion
- DF Knee Extended
- DF Knee Flexed
- Achilles Resting Angle

Supine

Prone

Closed Kinetic Chain

Forefoot
- *Hallux A*/PROM*
- *Forefoot**

Midfoot
- MLAA*
- *Navicular Hgt**

Rearfoot
- Plantar Flexion
- DF Knee Extended
- DF Knee Flexed
- *Inv/Eversion**

**Assessed dynamically with movement*

Foot Range of Motion: Dynamic Motions

Closed Kinetic Chain

	Motion	Measurement Method	Criteria	Limb Comparison
Dynamic	(Medial) Longitudinal Arch Angle	Goniometer/Phone*	Low: <131° | Normal:131-152° | High: >152°[3,4]	90% LSI &/or 90% of expected for condition/surgery
	Standing Rotation	Electronic Goni/Phone* Observation	Inversion: 20° Eversion: 10° 2:1 | Inv:Evr	
	Double Limb Squat	*Clinician Expertise*	Pronation & Re-supination	
	Modified Spring Ankle (Navicular Height)‡	Transparent Ruler Or Tape Measure	❑ <3-5 mm drop from NWB to WB[1] ❑ Achieve knee 2" over toe[1] ❑ Able to achieve >45° foot relative to floor[1]	

Note. *, traditional goniometer acceptable; ‡, part of 'Muscle Performance' assessment(s)

Inter-Rater Reliability: ICC 0.81[9]
Intra-Rater Reliability: ICC 0.90[9]
Test-Retest Reliability: 2.8-7.5°[10]

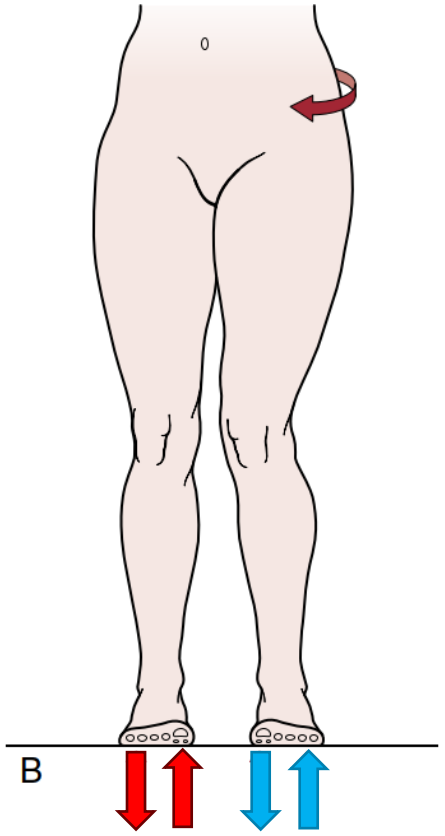
Clinical Observation
Reliability: Not Established
3D Motion Capture[7]
Test-Retest Reliability: 0.72
Pro/Supination Reliability: 0.95
Coefficient of Determination: R^2: ≥0.90

Munuera-Martínez 2020[1], Khuc 2023[2], Magee & Manske 2021[3], Cook 2010[4], Carmont 2014[5], Dutton 2012[6] , Edo 2017[7] Fraser 2006[8], Jonson & Gross 1997[9], Caravaggi 2019[10]

Fore/Midfoot Range of Motion: Dynamic Rotation

Forefoot & Rearfoot Mobility
Closed Kinetic Chain

Forefoot Closed Kinetic Chain

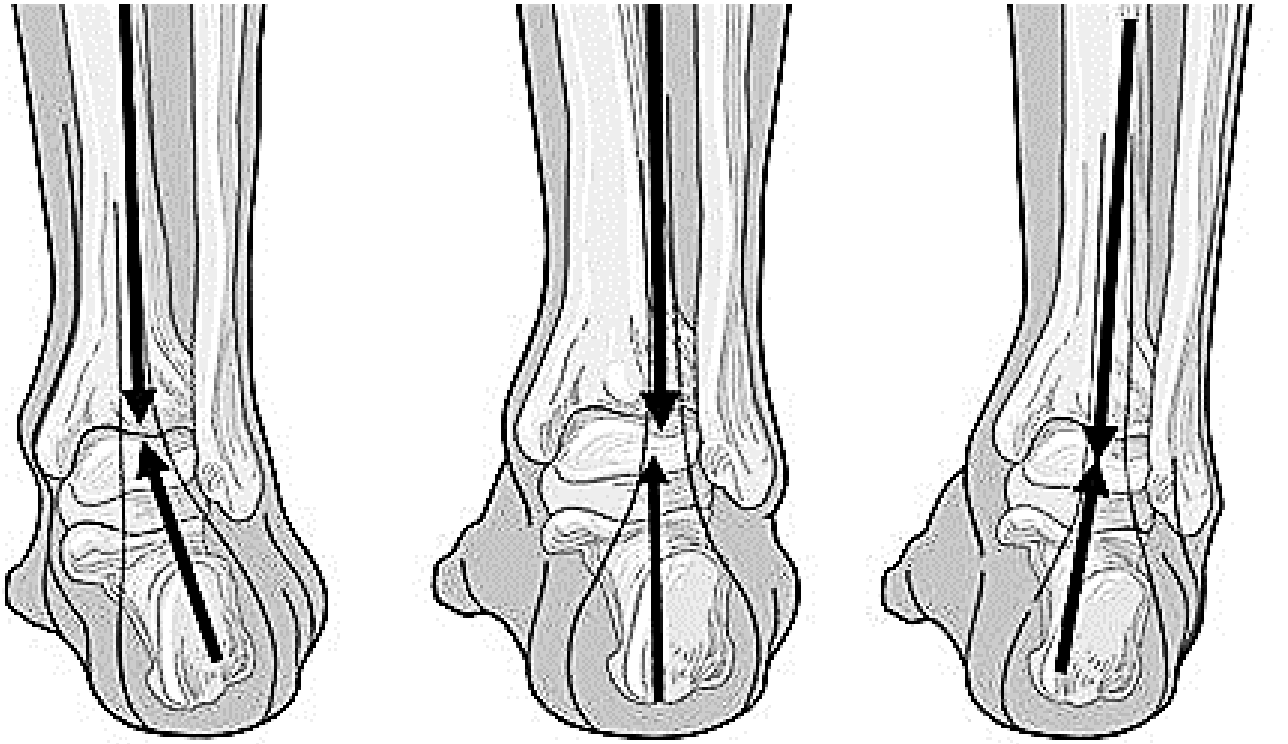


Supination

Pronation

Rearfoot Range of Motion: Dynamic Rotation

Rearfoot Mobility Closed Kinetic Chain



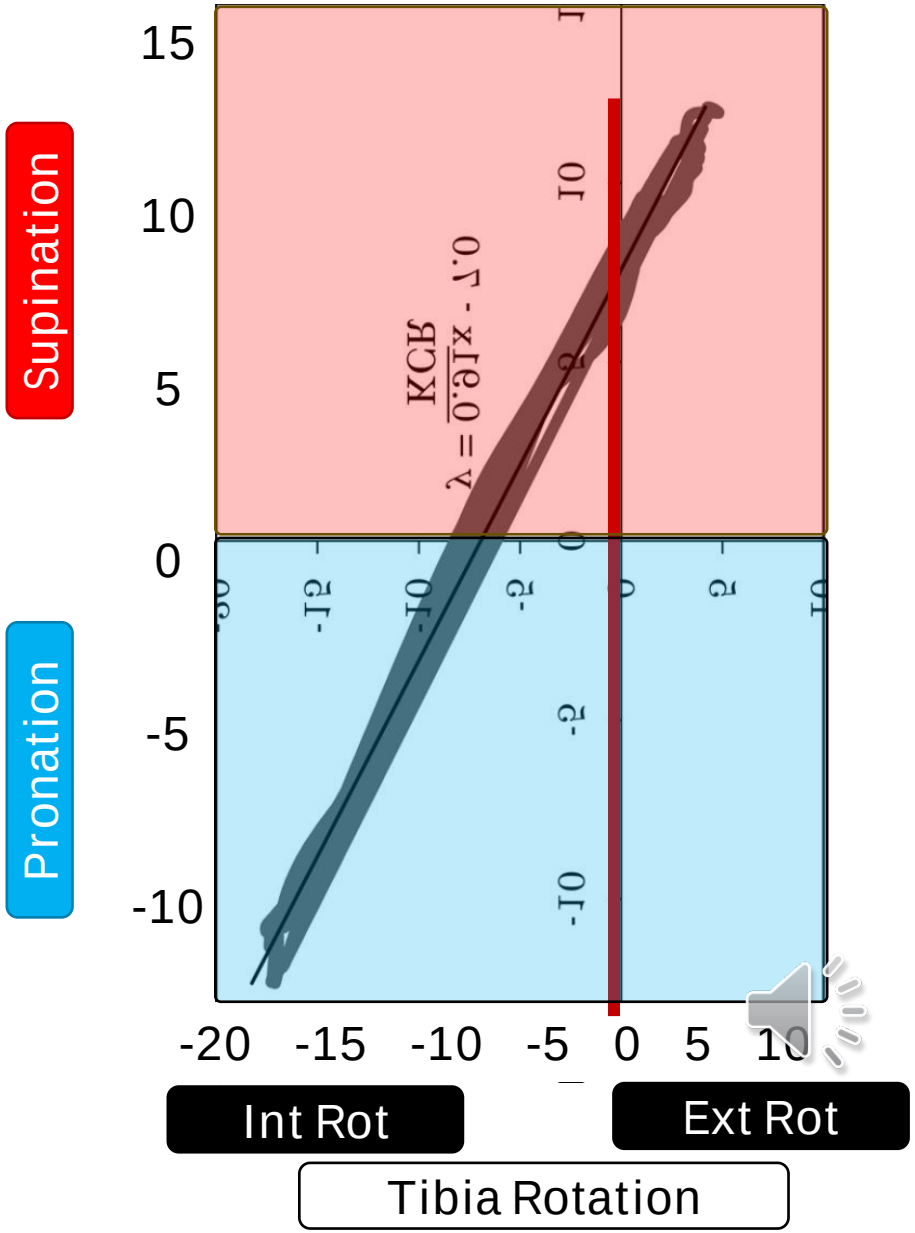
Pronation (right foot)

Neutral (right foot)

Supination (right foot)

.

Edo 2018



Medial Longitudinal Arch

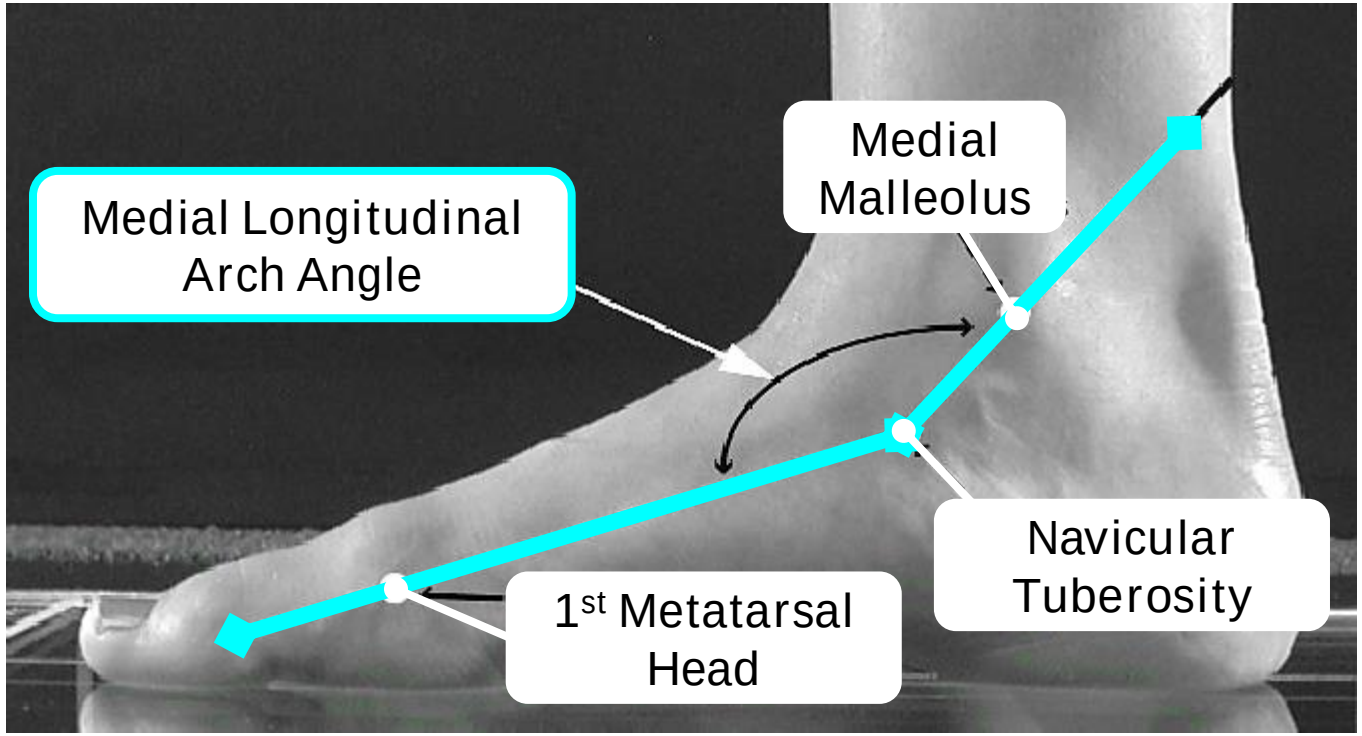
Clinical Significance

- The Longitudinal Arch Angle (LAA) (first described by Dahle[1]) has been reported to have a high degree of reliability & to be predictive of dynamic foot
- LAA is highly predictive of dynamic foot posture during walking & running.[2]
  - The static LAA explained >85% of the LAA at midstance during walking at mid-support while running.[2]
- <140° LAA cutoff values have been associated with medial tibial stress syndrome in folk dancers[4]

Dahle 1991[1], McPoil 2007[2], Bade 2016[3], Sommer & Vallentyne 1995[4]

Medial Longitudinal Arch Assessment

- ☐ Patient Position
  - *Seated*
  - *Double leg stance*
  - *Single leg stance*
- ☐ Measurement Tool
  - *(Electronic) Goniometer*
  - *Phone Angle Application*
- ☐ Start Ankle @ ~0° PF



Low Arch: <131° | Normal: 131-152° | High Arch: >152°[3,4]

Inter-Rater Reliability: ICC 0.81[2]
Intra-Rater Reliability: ICC 0.90[2]
Test-Retest Reliability: 2.8-7.5°[5]

Fraser 2017[1] , Jonson & Gross 1997[2], Nilsson 2012[3],Di Stasio 2020[4], Caravaggi 2019[5]

Foot & Ankle Range of Motion

Open Kinetic Chain

Forefoot
- Hallux
- 1st Ray
- Forefoot

Midfoot
- Cuboid
- Navicular
- FF Locking

Rearfoot
- Inv/Eversion
- Plantar Flexion
- DF Knee Extended
- DF Knee Flexed
- Achilles Resting Angle

Supine

Prone

Closed Kinetic Chain

Forefoot
- Hallux A/PROM
- *Forefoot**

Midfoot
- *MLAA**
- *Navicular Hgt**

Rearfoot
- Plantar Flexion
- DF Knee Extended
- DF Knee Flexed
- *Inv/Eversion**

**Assessed dynamically with movement*

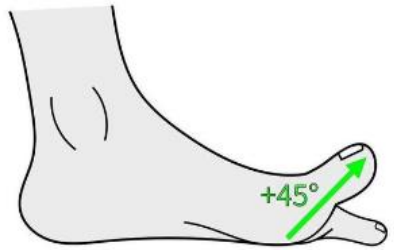
Foot Range of Motion: Dynamic Motions

Closed Kinetic Chain (CKC)

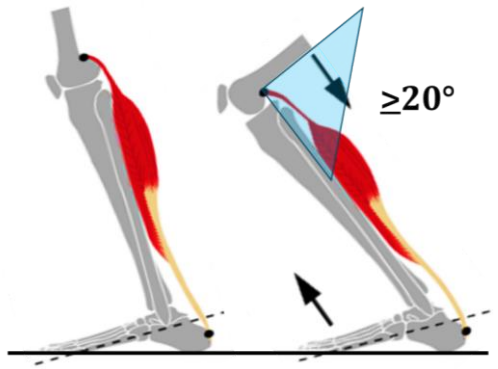
		Motion	Measurement Method	Criteria	Limb Comparison
Static	Forefoot	Hallux (MTP) PROM	Goniometer/Phone*	PROM Extension: 70°[3] AROM Extension: 65-70°[2,3,6]	90% LSI &/or 90% of expected for condition/surgery
	Rearfoot	Dorsiflexion (Knee Extended)	Inclinometer	Stride Stance: 24±6°[2] Tandem: Forefoot Clearance[4]	
		Dorsiflexion (Knee Flexed)	Tape Measure	½ Kneeling/Lunge: 40±7°[2,7,8]	
		Plantar Flexion†	Phone*	Heel Height: ≥ 8 cm‡ Foot Angle: ≥30°[4]	

Note. *, traditional goniometer acceptable; ‡, dependent upon foot length & anthropometrics

†Ankle; plantar flexion CKC is assessed as a part of 'Muscle Performance' given the antigravity nature of the assessment



Inter-Rater Reliability: 0.88-0.91[6]
Test-Retest Reliability: 0.82-0.93[6]
Criterion Validity (Xray): -13°[12]



Inter-Rater Reliability: ICC 0.96-0.99[2]
Intra-Rater Reliability: ICC 0.72-0.99[11]
SEM Digital Inclinometer: 1.3-1.4°[9]
SEM Tape Measure: 0.18 cm[10]
MDC Weightbearing Lunge: 3.8-4.7°[10]

Munuera-Martínez 2020[1], Baumbach 2014[2], Magee & Manske 2021[3], Cook 2010[4], Carmont 2014[5], Dutton 2012[6], Driller 2017[7], Dill 2014[8], Koner 2012[9], Paço 2012[10], Powden 2015[11], Vulcano 2014[12]

Ankle Range of Motion: Dorsiflexion (CKC)

Johanson 2014

The Effect of Subtalar Joint Position on Dorsiflexion of the Ankle/Rearfoot Versus Midfoot/Forefoot During Gastrocnemius Stretching

Study Design: Repeated Measures

Subjects:

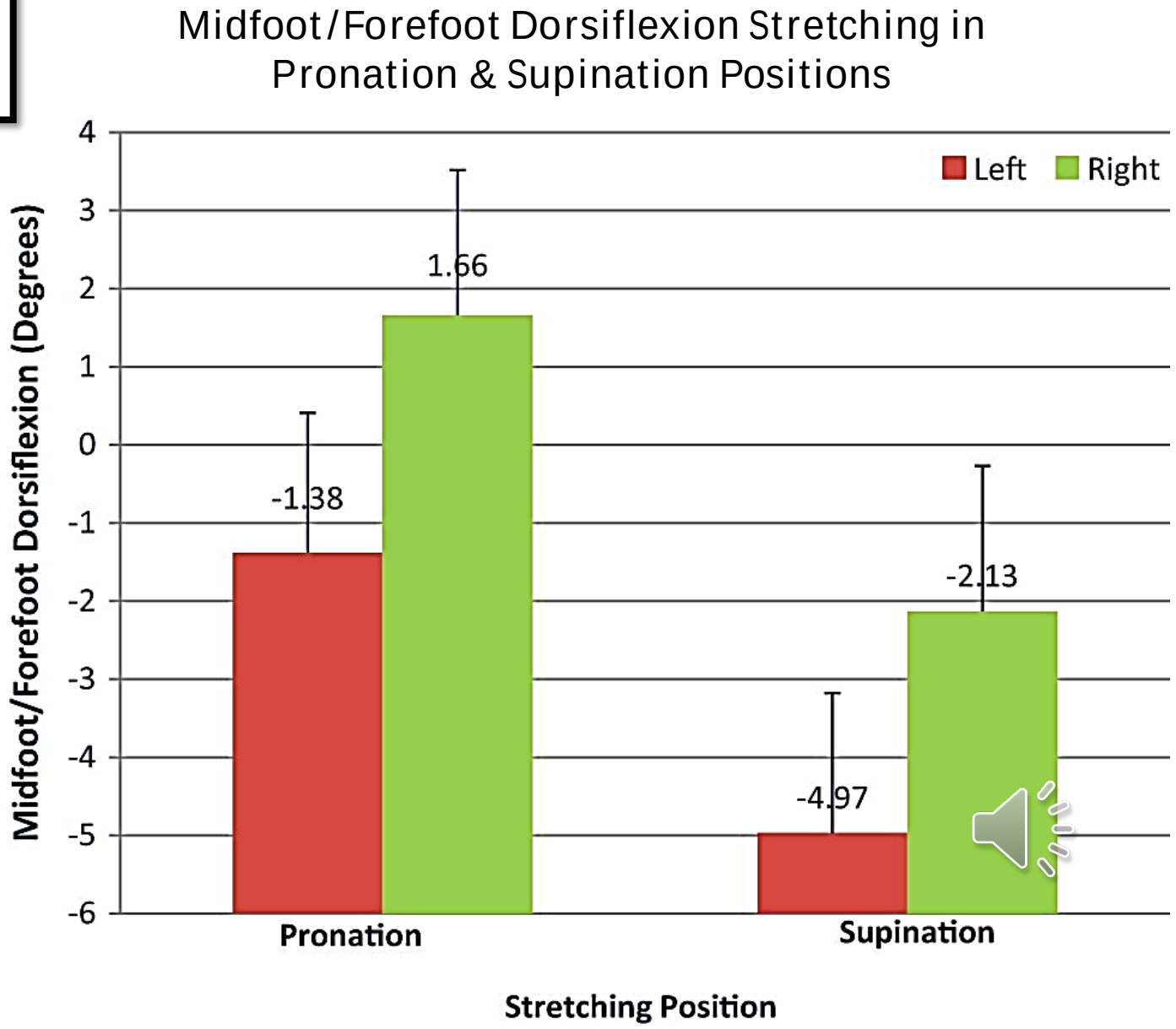
- Recruitment: University & Recreation Running Clubs (Atlanta, GA)
- *n* = 27 (23:4 | F:M), Age: 31.3±10.7
- Current or recent lower extremity chronic condition w/ limited DF

Instrumentation:

- Vicon Motion Analysis 7 Camera System
- AMTI Force Plate

Outcomes:

- Midfoot/forefoot Dorsiflexion
- Ankle/rearfoot Dorsiflexion
- Ground Reaction Force

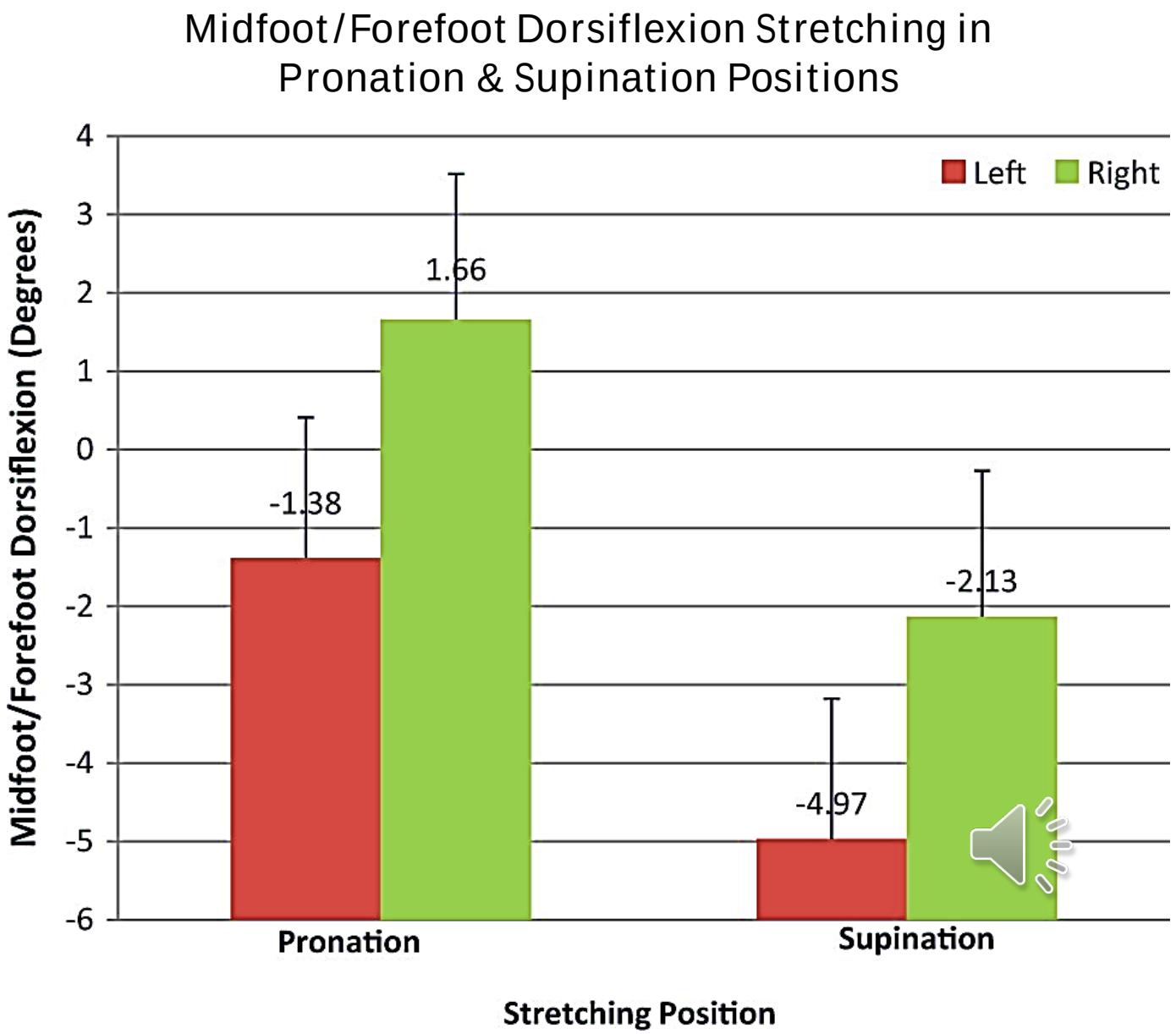


Ankle Range of Motion: Dorsiflexion (CKC)

Johanson 2014

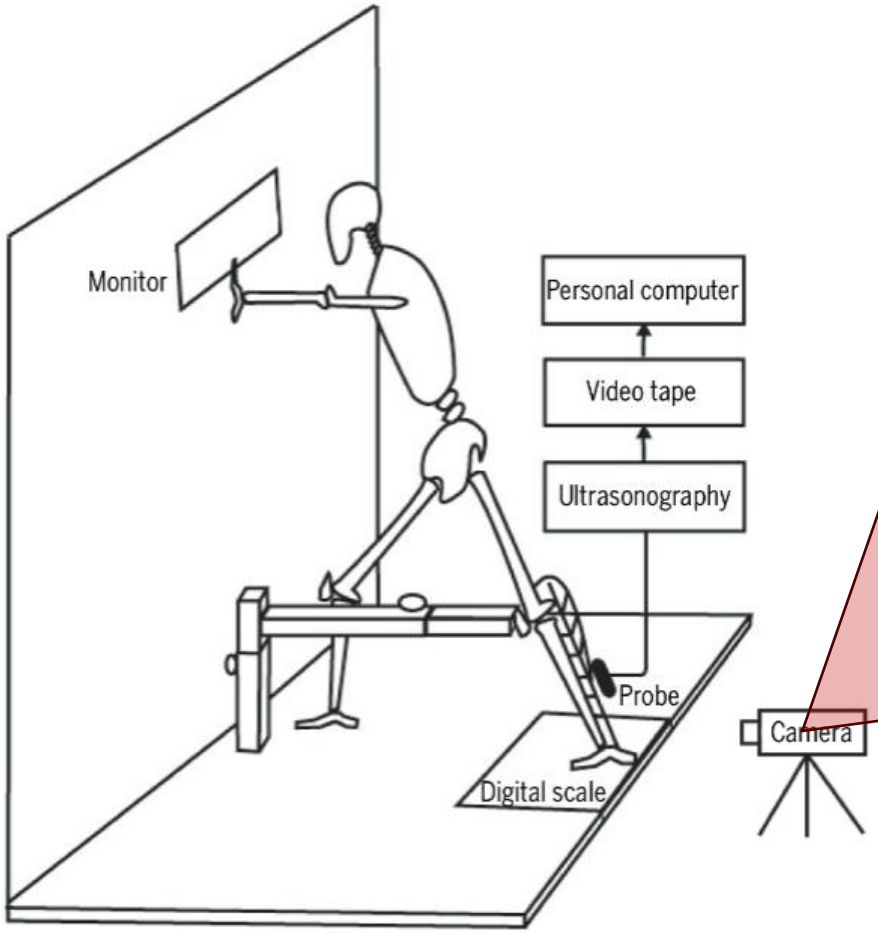
Conclusion:

- CKC DF performed with the STJ positioned in *subtalar joint neutral (supination)* significantly ⬇ dorsiflexion contributions at the midfoot/forefoot (vs pronated position)
- Clinicians may want to consider STJ position during gastrocnemius stretching (i.e., CKC DF) to either facilitate or limit recruitment of dorsiflexion motion at the midfoot/forefoot.



Ankle Range of Motion: Dorsiflexion

Jung 2009



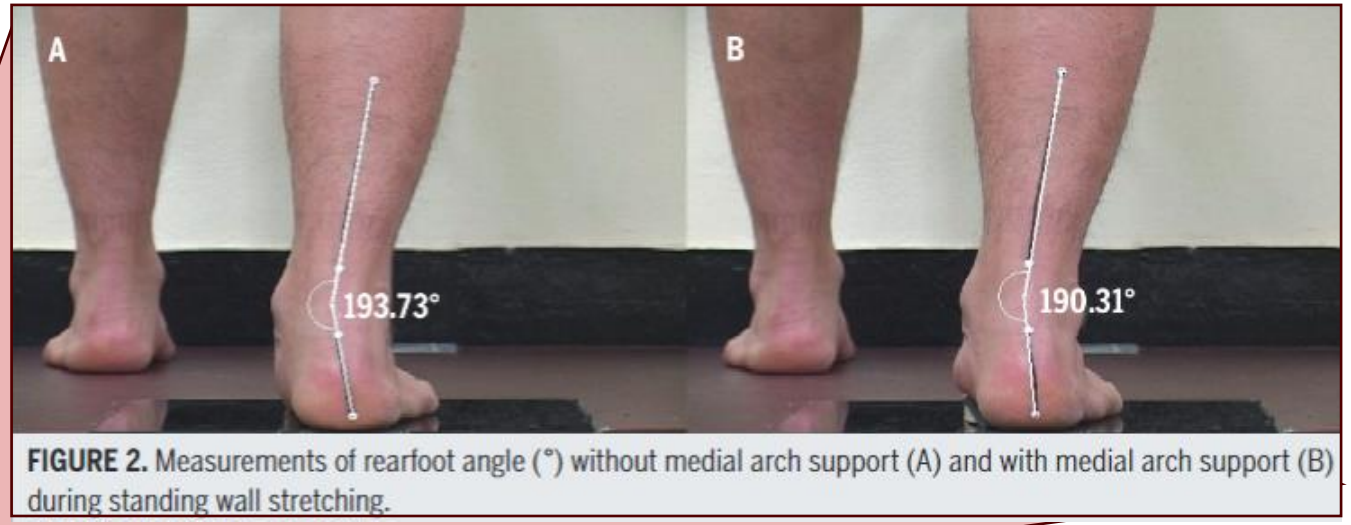


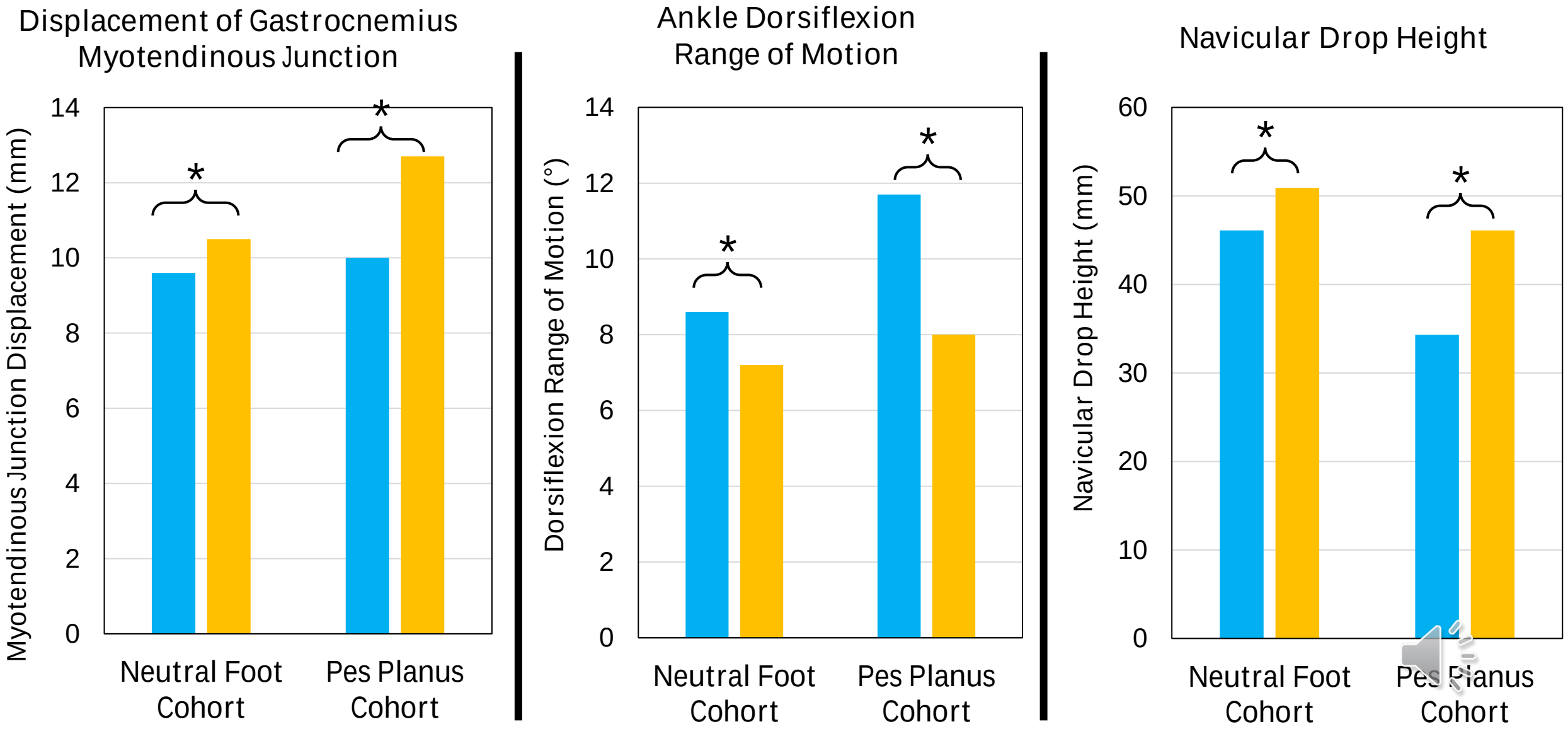
FIGURE 2. Measurements of rearfoot angle (°) without medial arch support (A) and with medial arch support (B) during standing wall stretching.

Medial Arch Support

- Neutral Foot Type Cohort: resting calcaneal stance position ±2° & navicular drop 5 – 9 mm
- Pes Planus Foot Type Cohort: resting calcaneal stance position ±>4° & navicular drop ≥13 mm

Ankle Range of Motion: Dorsiflexion

Jung 2009 | *$p < 0.001$



Ankle Range of Motion: Dorsiflexion (CKC)

The influence of knee position on ankle dorsiflexion - a biometric study

Study Design: Repeated Measures

Subjects: Healthy

- *n* = 20 (10:10 | F:M), Age: 18-40 yrs

Methods:

- Blinded assessors
- Standard Goniometer
- CKC Ankle DF measured knee flexion angles:
  - 0°, 20°, 30°, 45°, 60°, 70°, Lunge

Outcomes:

- Ankle dorsiflexion

Weight Bearing Condition

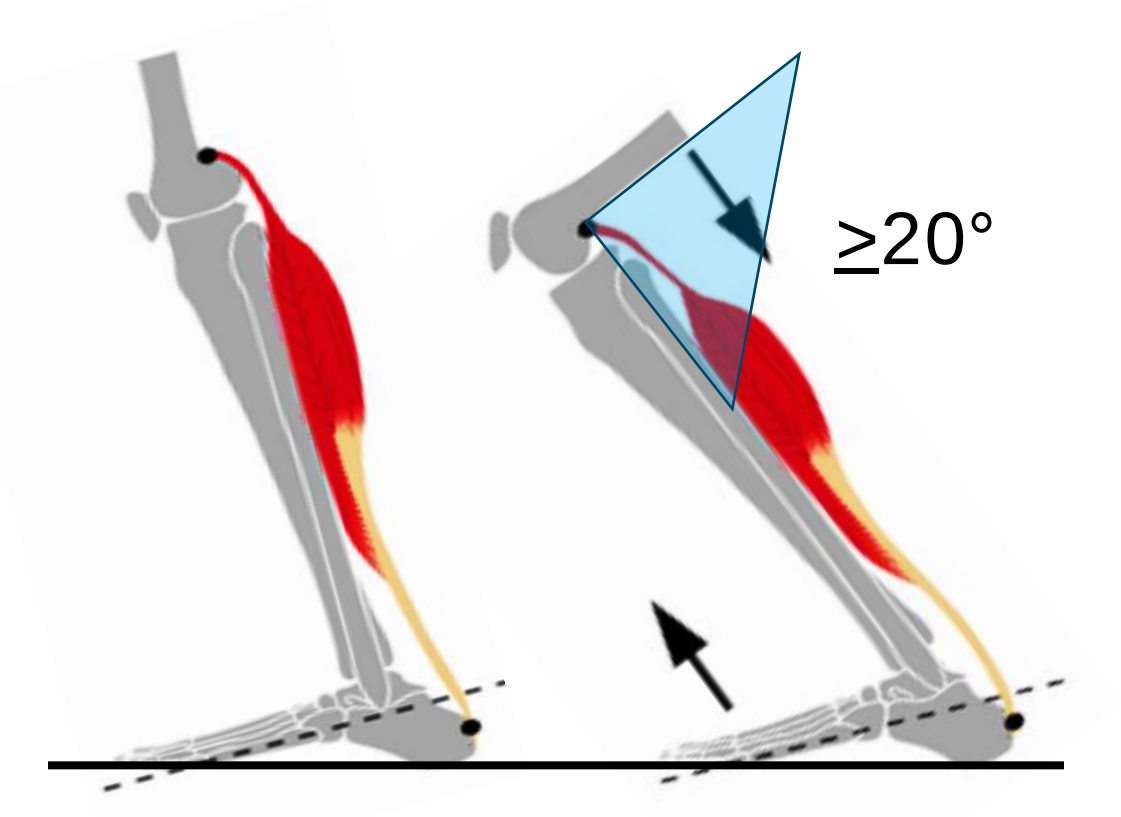
Lunge Condition

Baumbach 2014

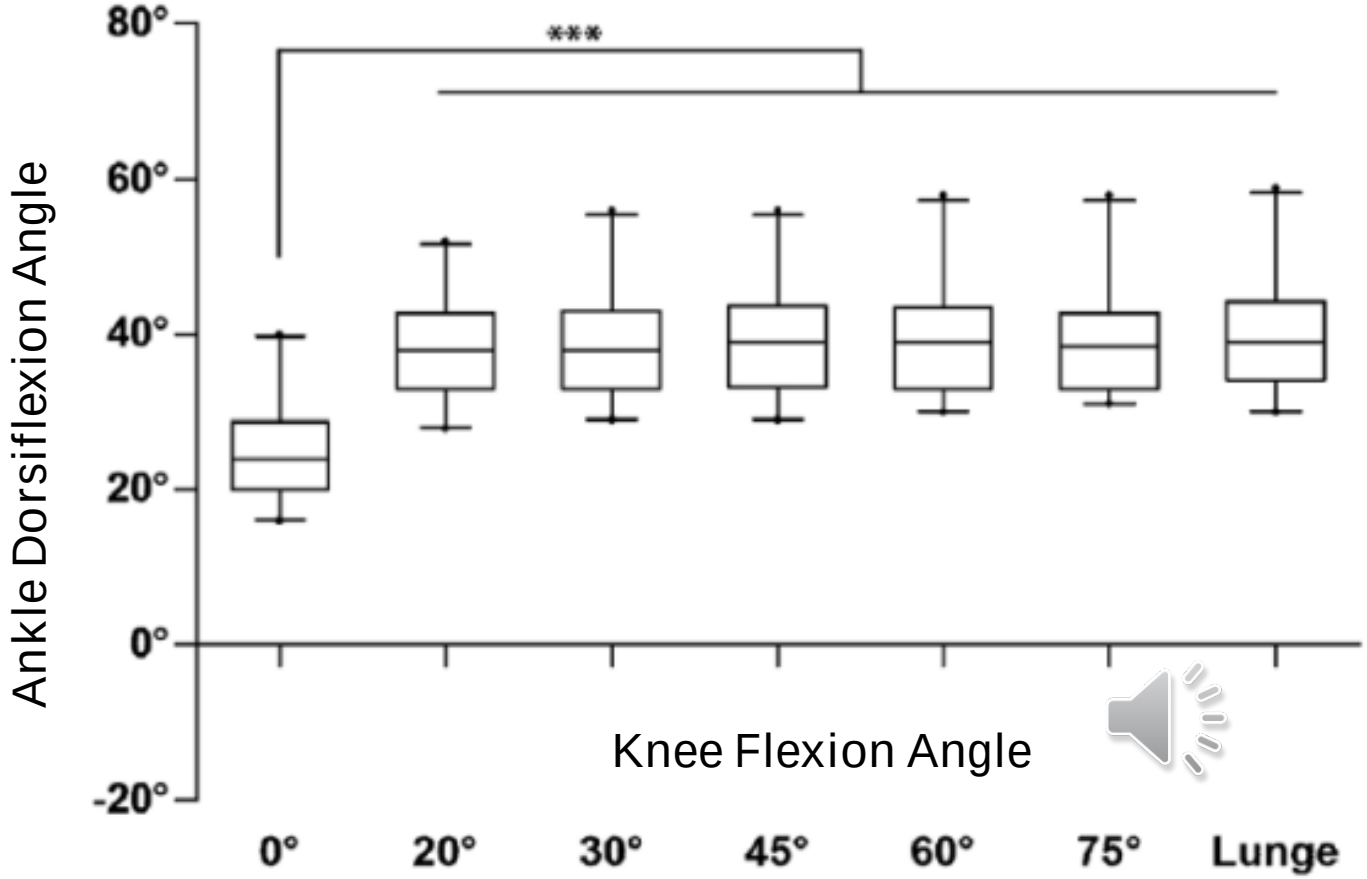
Ankle Range of Motion: Dorsiflexion (CKC)

The influence of knee position on ankle dorsiflexion - a biometric study Baumbach 2014

≥20° of knee flexion fully eliminates the restraining effect of the musculus gastrocnemius on DF, both non NWB & WB conditions



Weight Bearing Ankle Dorsiflexion Range of Motion

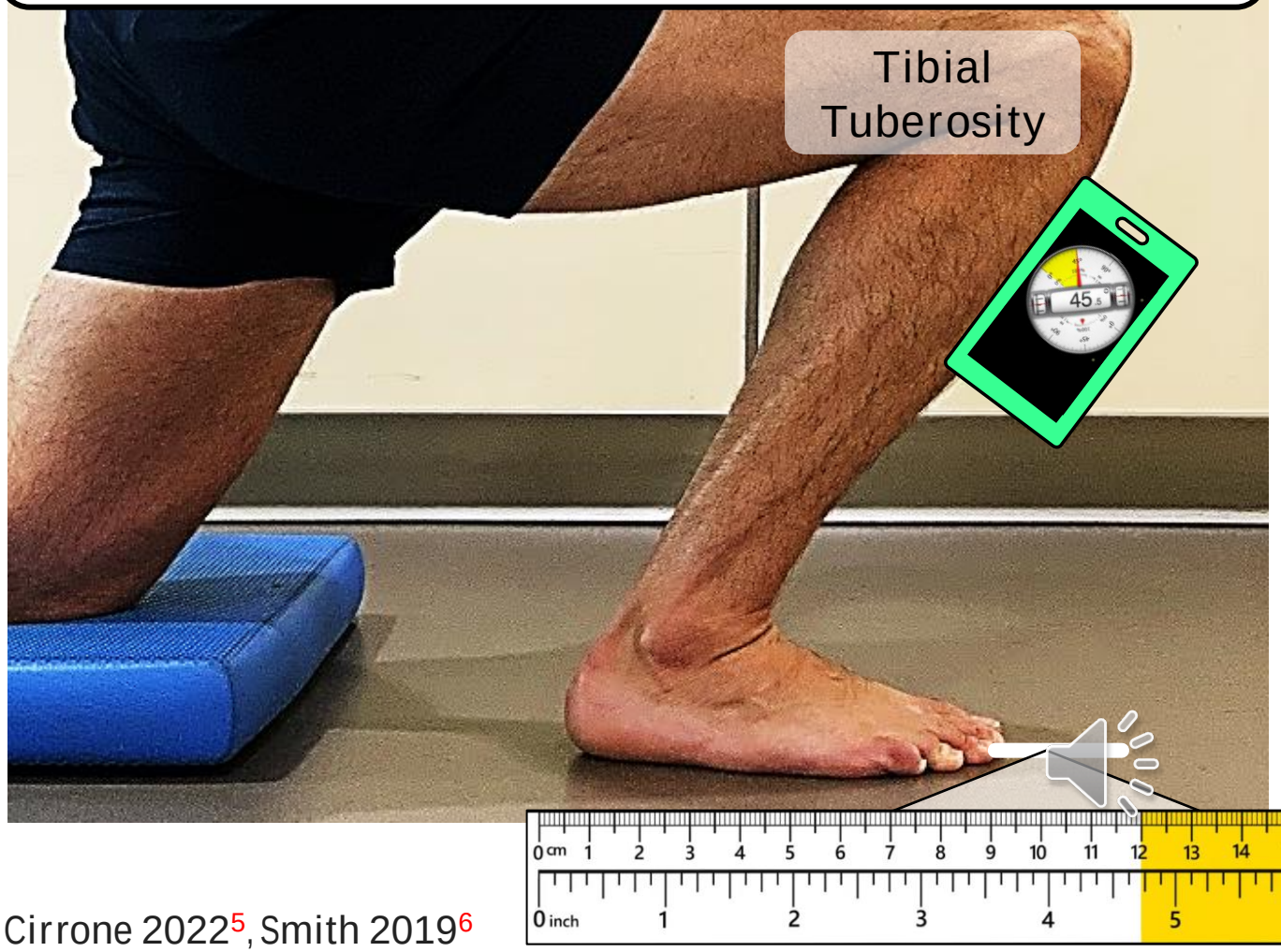


Ankle Range of Motion: Dorsiflexion CKC

- ☐ Patient Position
  - *½ Kneeling, barefoot*
  - *Subtalar & pelvis neutral*
  - *medial arch support, heel down*
- ☐ Measurement Tool
  - *(Electronic) Goniometer*
  - *Phone Angle Application*
- ☐ Start Ankle @ ~0° DF

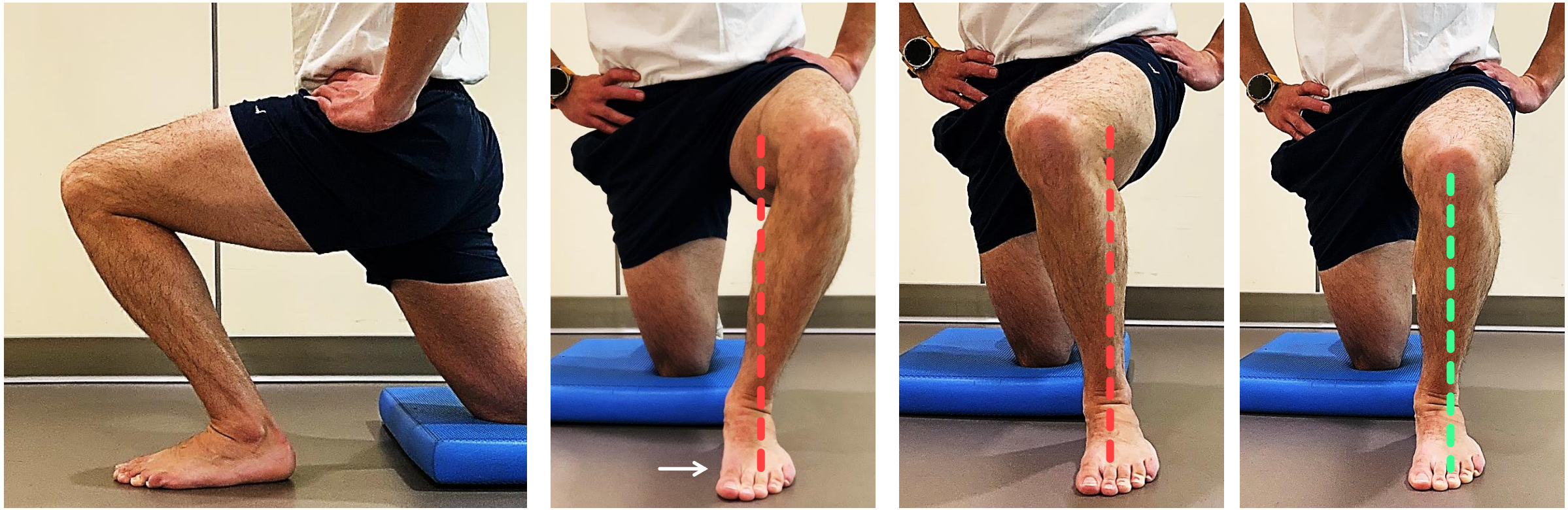
XR vs Tibial Inc. Correlation: *r* = 0.94[6]
Inter-Rater Reliability: 0.93-0.99[1] | 0.85-0.97[2]
Intra-Rater Reliability: 0.85-0.98[2]
SEM: 0.88-1.82°[2] | 0.13-0.16cm[4]
MDC: 2.4-5.0°[2]
Meaningful Asymmetry: >5°[5] | 1.5 cm[5]

Degrees: >40° (<34° = 5x ⬆ risk of LAS)
*Distance: >10 cm (M: 12.1-13.9 cm | F: 13.6-14.9 cm)[3]
**Note.* tibia & foot length may be confounding variables



Chisholm 2012[1], Banwell 2018[2], Gohil 2022,[3] Hoch 2011,[4] Cirrone 2022[5], Smith 2019[6]

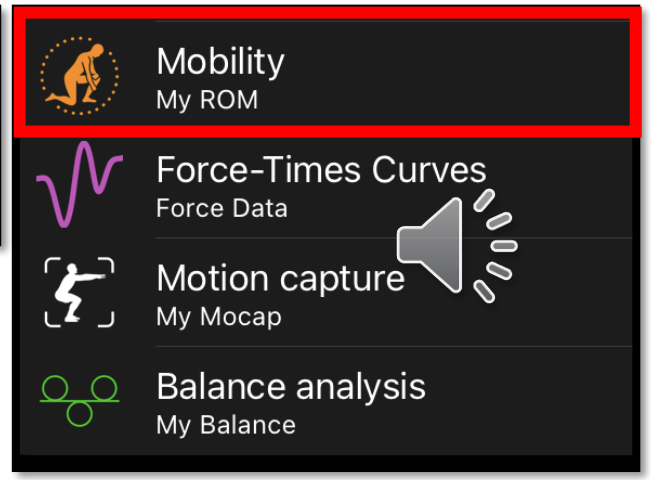
Ankle Range of Motion: Dorsiflexion (CKC)



Closed Kinetic Chain Dorsiflexion Pro Tips:

- Barefoot, ½ Kneeling Lunge
- Subtalar neutral w/ medial arch support
- Control: pelvic rotation, knee varus/valgus, heel elevation

My Jump Lab



Clinically Significant

KEY POINTS

Foot & Ankle Range of Motion

Open Kinetic Chain

Forefoot

- Hallux: PF:45°| DF:70°
- 1st Ray: PF & DF: 5 mm
- Forefoot: INV: >45°|EV>15°

Supine

Rearfoot

- INV: 20°|EVR: 10°
- PF: 50°
- DF Knee Ext: ≥20°
- DF Knee Flx: ≥30°
- ATRA Ruptured: 55°±8°
- ATRA Repaired: 37°±9°

Prone

Closed Kinetic Chain

Forefoot

- Hallux AROM: 70°
- Hallux PROM: >65°
- *Forefoot: Qualitative*

Midfoot

- *MLAA*:131-152°
- *Navicular Hgt**

Rearfoot

- PF: 30°| Hgt: 8 cm
- DF Knee Ext: 24±6°
- DF Knee Flx: 40±7°
- *INV*: 20°|*EVR*: 10°

Assessed dynamically with movement
**Navicular Hgt assessed with postural control assessment(s)*

Abbreviations: AROM, active range of motion; ATRA, Achilles tendon resting angle; cm, centimeter; DF, dorsiflexion; EVR, eversion; EXT, extended; FLX, flexed; Hgt, height; INV, inversion; MLAA, medial longitudinal arch; mm, millimeters; PF, plantar flexion; PROM, passive range of motion.