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REESTABLISHING ATHLETIC MOVEMENT AND BUILDING STRENGTH POST-OP ACLR: A GUIDE ON HOW TO REINTEGRATE THE ATHLETE BACK INTO FULL ACTIVITY

PRE-OP/POST-OP AND EARLY TO MID PHASE STRENGTH CONSIDERATIONS FOR ADDRESSING SURGICAL ASYMMETRIES

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CONFLICT DISCLOSURE:

- I have no conflicts of interest.
- Views expressed are based on my own clinical experience.
- Views may not be the same as my employer or colleagues.
- Please use discretion when using the information contained in this presentation as ACLR rehabilitation is not a cookie cutter approach.

CONTENT COVERAGE CHECK LIST:

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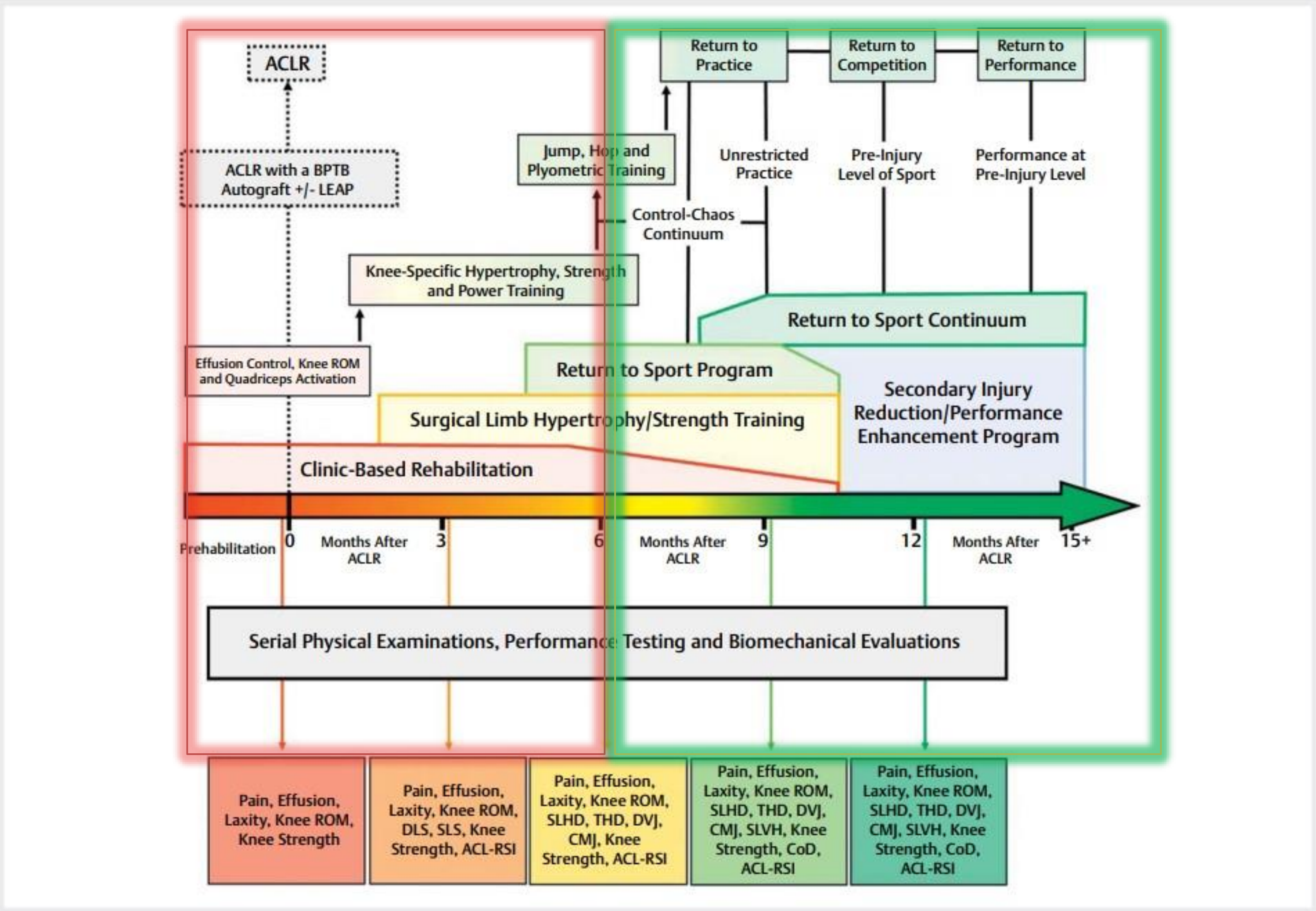
- Guidelines for the Integration of Plyometric Progressions
- 6-7 Month Progress Test

ACLR REHAB CONTINUUM:



(SOLIE ET AL., 2024)

THE IMPORTANCE OF PREHABILITATION:

- Indicator of Early Knee Function Post-Op and Higher RTS Rates (Solie et al., 2024)
  – Prehab has been shown to reduce the following both Pre-Op and Post-Op: (Falia et al., 2016 ; Grindhem et al., 2015)
    - Joint Pain, Joint Effusion, Quadriceps Atrophy and Dysfunction, Knee ROM Restrictions
  – 72% of athletes who completed Prehab vs 63% of athletes who did not (Falia et al., 2016)
    - Returned to pre-Injury level of sport at 2-year follow-ups
  – Six weeks of prehabilitation was shown to reduce RTS times (Sharaani et al., 2013)
    - 42.5 weeks without prehab >>>>> 34.2 weeks with prehab

***Advocate for your Patients and Normalize Knee Function Prior to ACLR!

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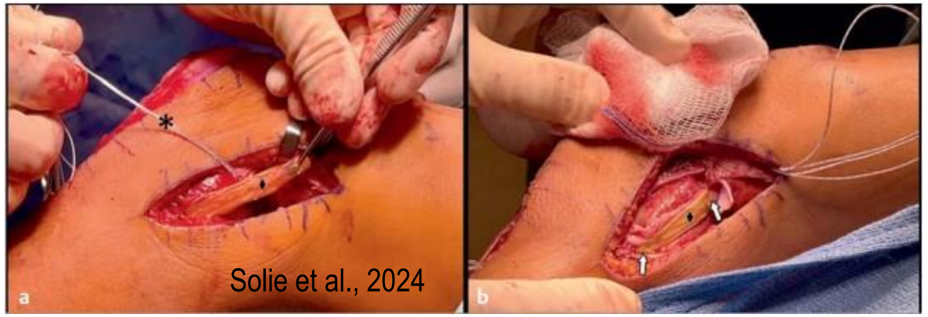
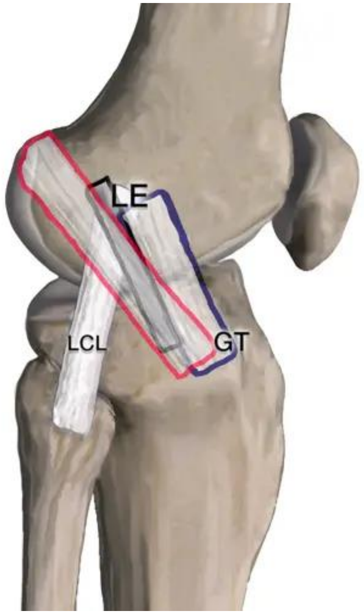
CONSIDERATIONS FOR PROGRAMMING REHAB POST-OP ACLR:

- Graft Type?
  - Bone Patellar Tendon Bone (BPTB)
  - Quad Tendon (QT)
  - Hamstring Tendon (HT)
  - Autograft vs Allograft
  - Contralateral Autografts
- Lateral Extra-Articular Procedures (LEAP)?
  - Anterior Lateral Ligament (ALL)
  - Lateral Extra-Articular Tenodesis (LET)

*** Both Serve to Decrease the Anterolateral Laxity of the Knee



Solie et al., 2024



Red: LET
Black: ALL
Blue: CL

CONSIDERATIONS FOR PROGRAMMING REHAB POST-OP ACLR:

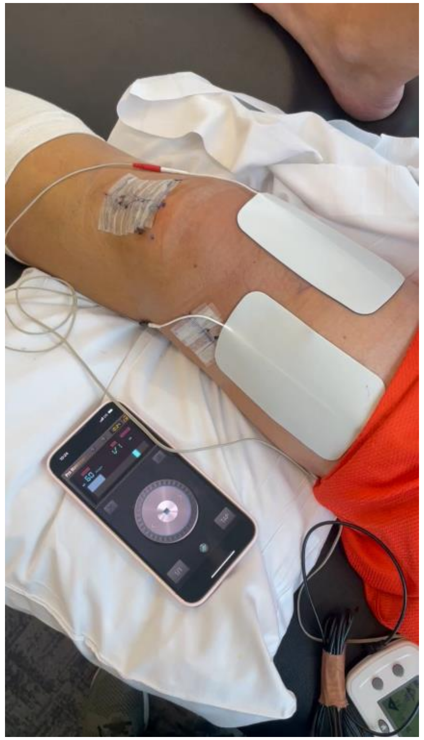
- Multi-Ligament?
  - MCL, LCL, PCL

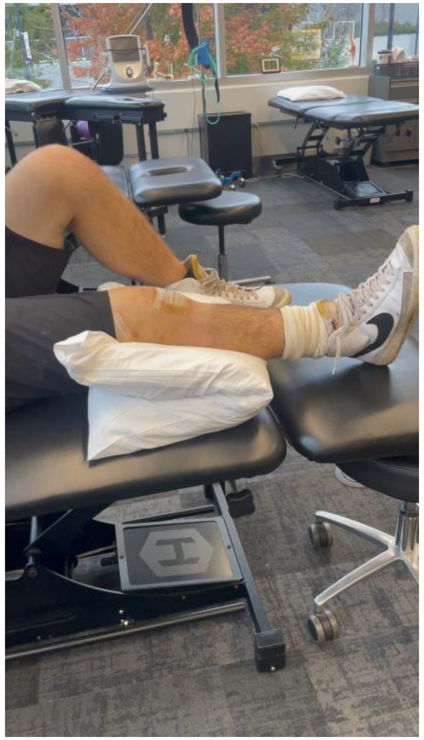
Statistically shown to reduce level of RTS and RTS Rates. (Solie et al., 2024)

- Meniscus Involvement?
  - Repair vs Partial Meniscectomy, ROM Restrictions, and Reactive Joint Effusion to New Stimuli
- Patient Age, Training Age, and Gender?
  - Helps Determine Intensity and Frequency of the Training Stimulus to Ensure Adaptation
- Sport or Activity the Patient is Returning To?
  - RTP Criteria, Integration of Plyometrics, and Programming Sport-Specific Accessory Movements
- Level of Activity the Patient Needs To Return?
  - Helps Determine your Pace of Progression and Programming Intensity in the Late Phases of Rehab

EARLY POST-EXERCISES: WEEKS 0-3

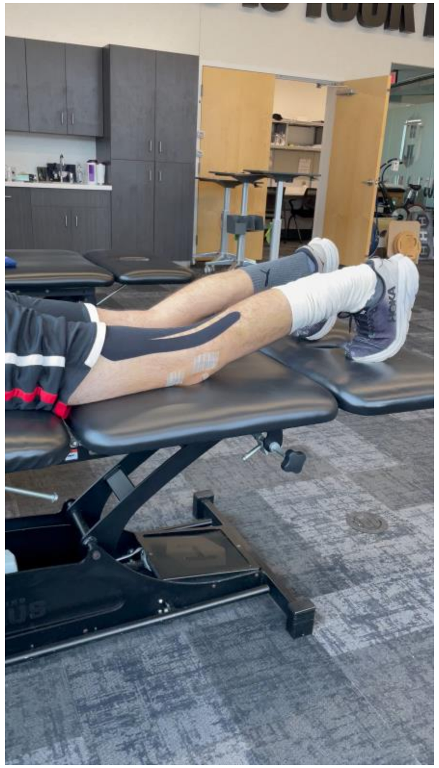
- Clinical Goal: Mitigate Quad Atrophy, Normalize ROM, and Decrease Joint Effusion

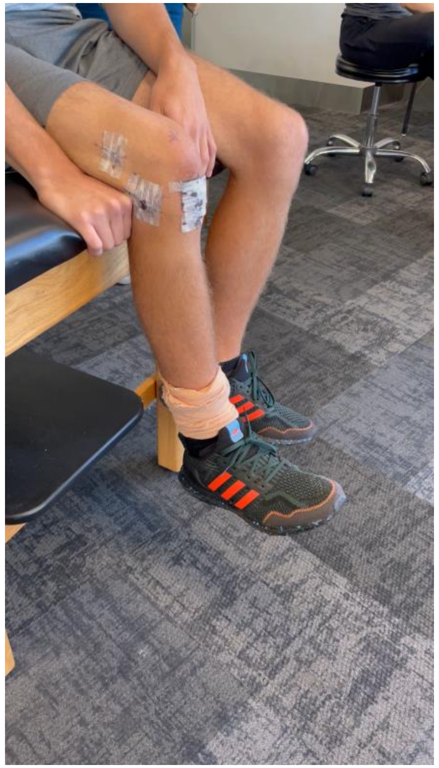




EARLY POST-EXERCISES: WEEKS 3-6

- Clinical Goal: SLR and LAQ Control, Normalize ROM, and Decrease Joint Effusion





EARLY POST-EXERCISES: WEEKS 6-8

- **Clinical Goal:** TKE Control, Tendon Tension, Normalize ROM, and Decrease Joint Effusion

EARLY POST-EXERCISES: WEEKS 8-10

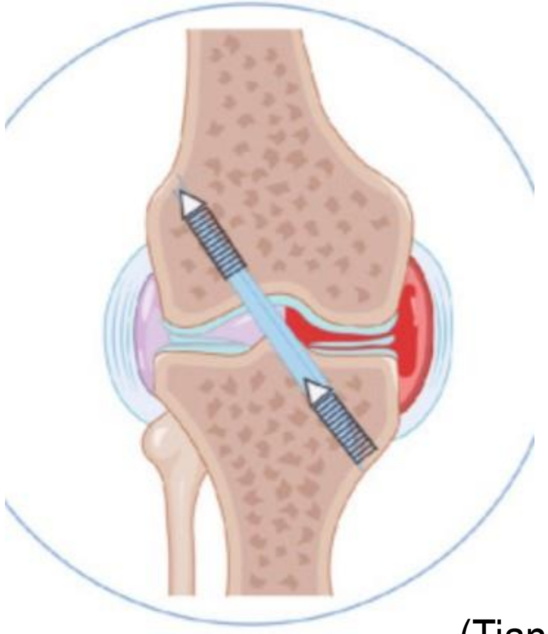
- **Clinical Goal:** Loaded TKE, Tendon/Quad Tension, Normalize ROM, and Decrease Joint Effusion

WHEN DO WE START STRENGTHENING? GOAL: WEEK 10-12 POST-OP

- Early-phase strength training can begin once the following goals have been met:
  - AMI has been addressed and patient has Sufficient Quad Activation (Week 0-10 Post-Op)
    - Quadriceps control over Quad Set, SLR, and TKE
    - **Clinical Observation:** 2-4 Weeks of Prehab has been Beneficial in Re-establishing Quad Activation Post-Op
  - Normalization of Range of Motion (Week 0-12 Post-Op)
    - Extension: WNL Bilaterally
      - Symptomatic Cyclops Lesions present in 1-11% of Post Operative ACLRs (Kambhampati et al., 2020)
    - Flexion: WNL Bilaterally
      - Arthrofibrosis present in 2-35% of Post Operative ACLRs (Sutanto, 2023)
    - **Clinical Observation:** LOSS OF MOTION IS LOSS OF FUNCTION!
  - Normalizing or Diminishing Joint Effusion (Week 0-16 Post-Op)
    - Graded Daily by Clinician via Sweep Test
      - 3+ / 2+ / 1+ / Trace / Phys / ~~0~~

WHAT HAPPENS WHEN WE START TOO SOON OR TOO FAST?

- Risk of Bone Tunnels Widening and Graft Loosening/Subsequent Failure
  - Physiologically, bone tunnels are at the highest risk for widening in the first 12 weeks (Sauer, 2017)
    - Exhibit caution with intensity and load of OKC exercises between 0-30 degrees of flexion during this time frame
- Knee Joint Pain/Tenderness/Irritability
  - Joint Effusion Increases
  - Hypertonicity of the Musculature Surrounding the Knee
  - Loss of ROM
- Quad Tendon/Patellar Tendon Pain
  - Occurs when the load isn't graded in intensity.
  - Leads to Movement Aversion/Dysfunction
  - May Lead to a De-Load Period if Severe Enough



(Tian et al., 2023)

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TRAC PROGRAM: BASELINE AND PROGRESS TESTING PROTOCOLS

* Indicates testing completed if patient is able starting at 6 months s/p

Strength

- Maximal Isometric Quadriceps Test @ 90^{o} knee flexion on Isokinetic Dynamometer (Biodex)
- Isokinetic Quadriceps/Hamstring at 60^{o}/sec

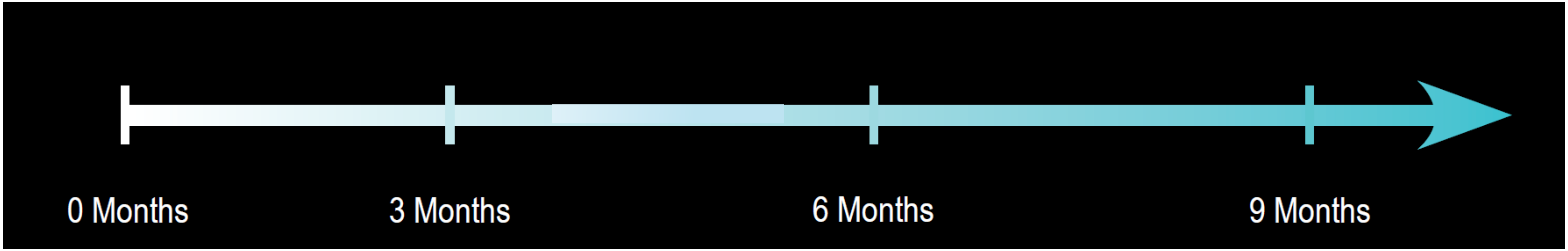
Power

- Counter Movement Jump (Vertical Jump) on bilateral force plates*

Coordination

All of the below performed on force plates under 3D motion capture

- Double Leg Squat
- Single Leg Squat
- Single Leg Forward Hop for Distance*



Surgery

Baseline TRAC Test

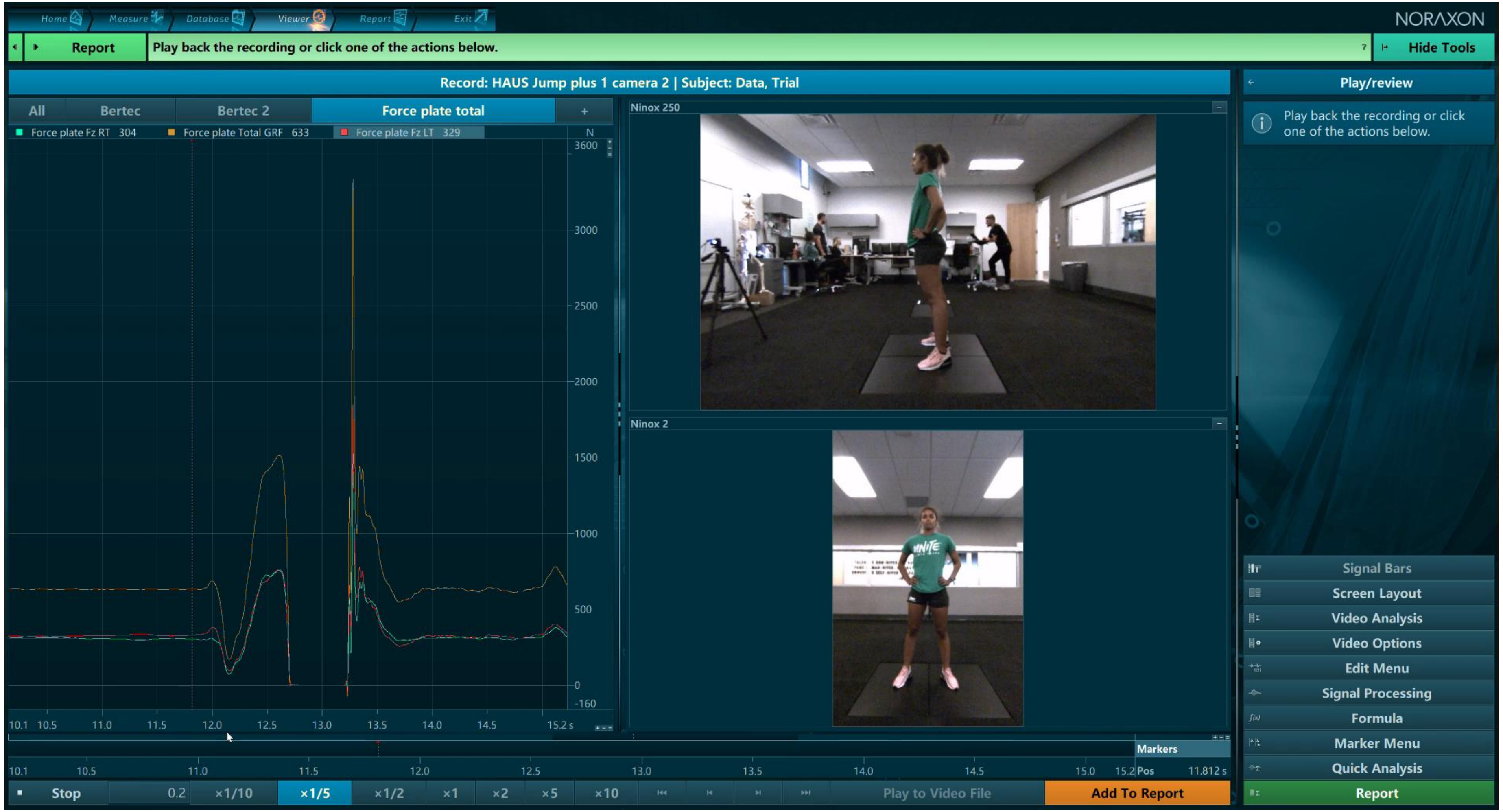
TRAC Test 2

TRAC Test 3

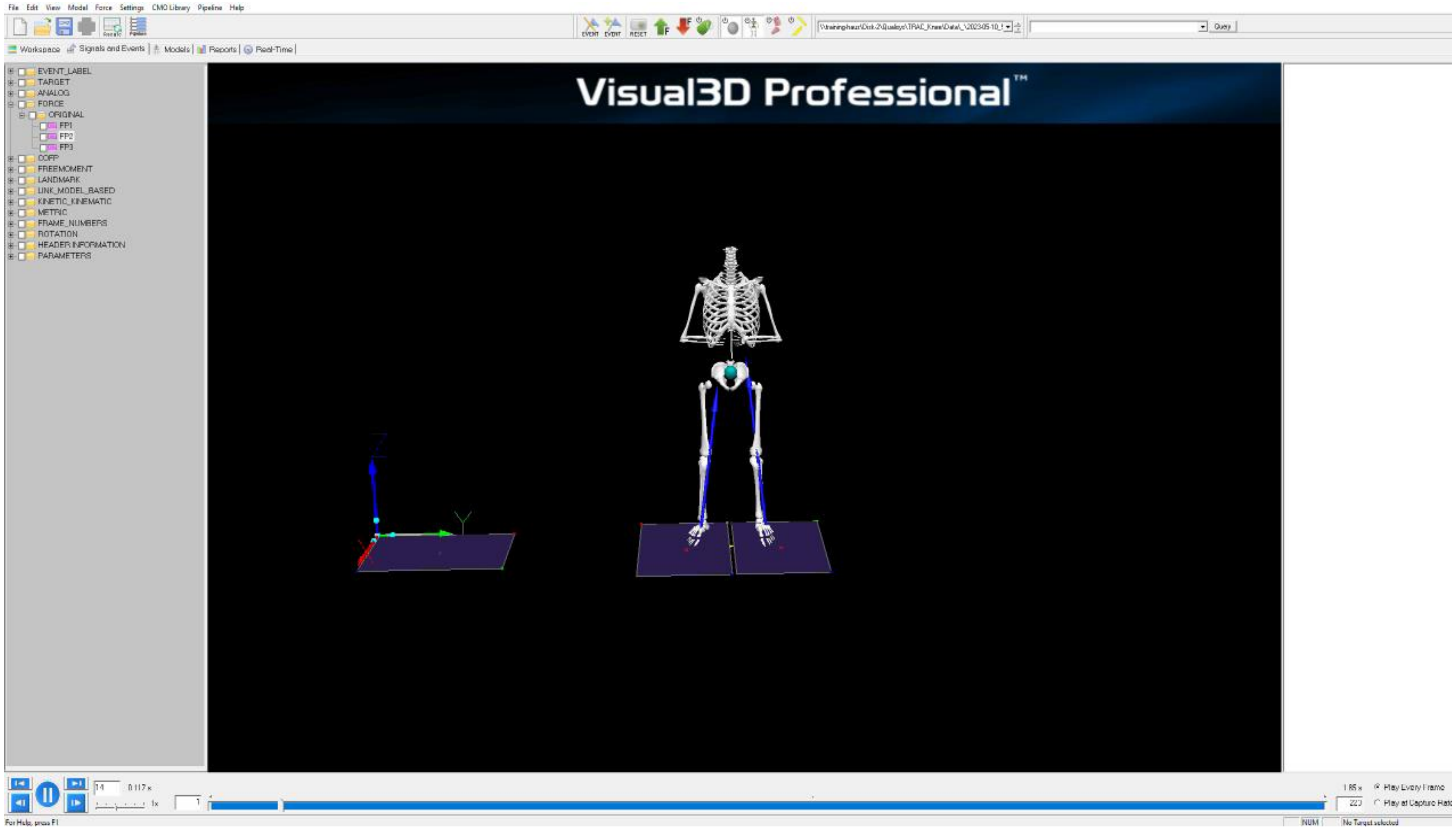
STRENGTH: 90 DEGREE QUADRICEPS ISOMETRIC

STRENGTH: 60 DEGREE/SEC QUADRICEPS/HAMSTRING ISOKINETIC

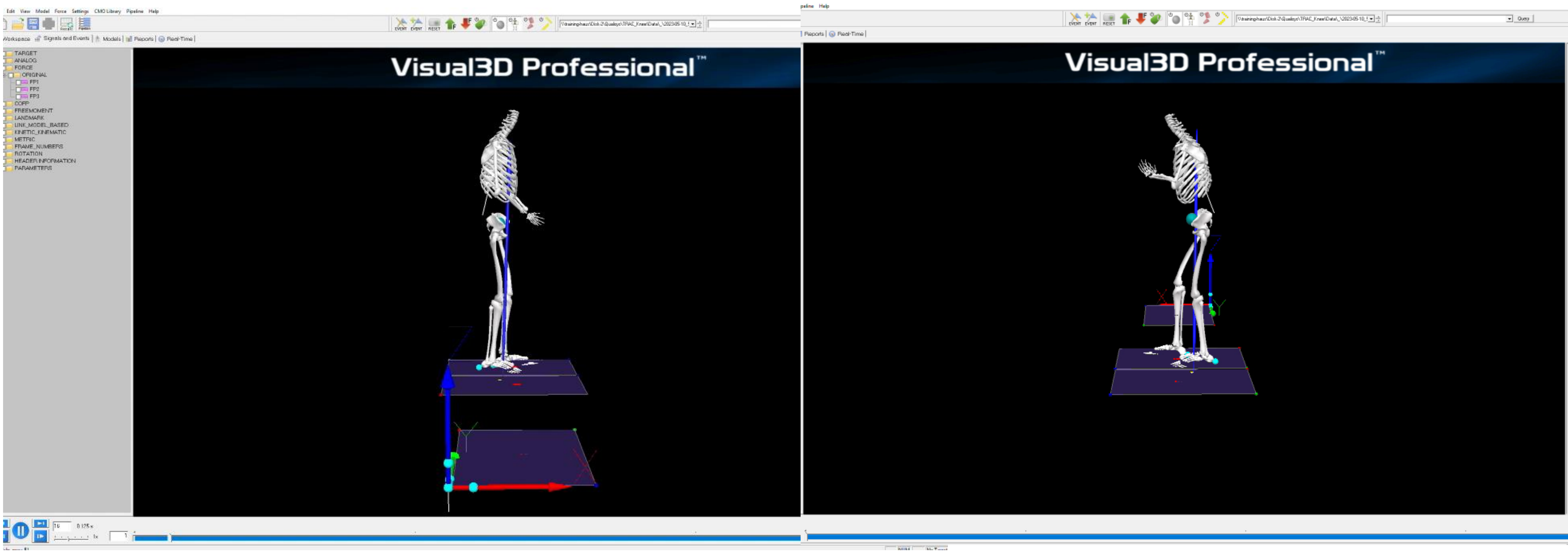
POWER: COUNTER MOVEMENT JUMP



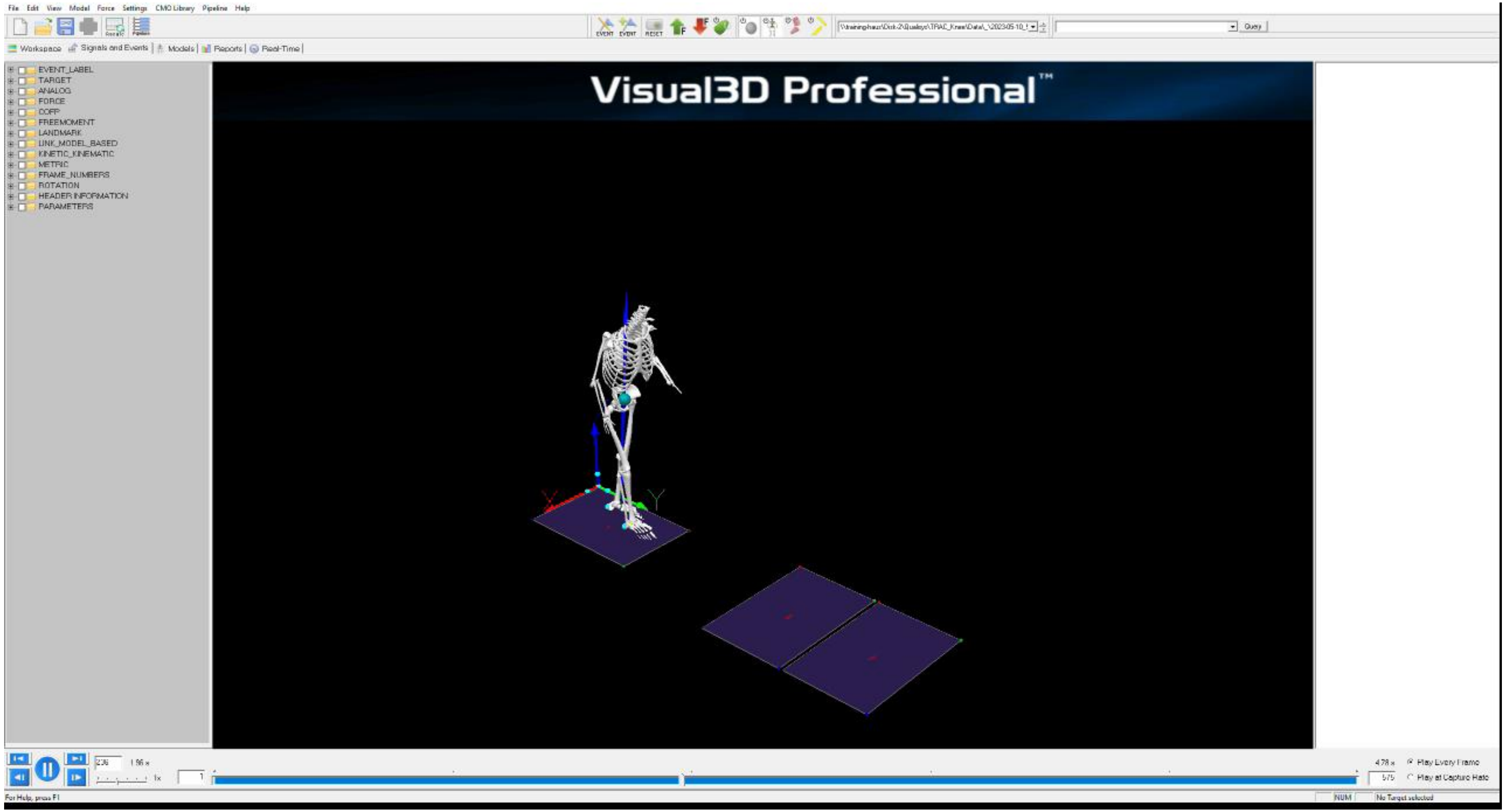
COORDINATION: DOUBLE LEG SQUAT MECHANICS



COORDINATION: SINGLE LEG SQUAT MECHANICS

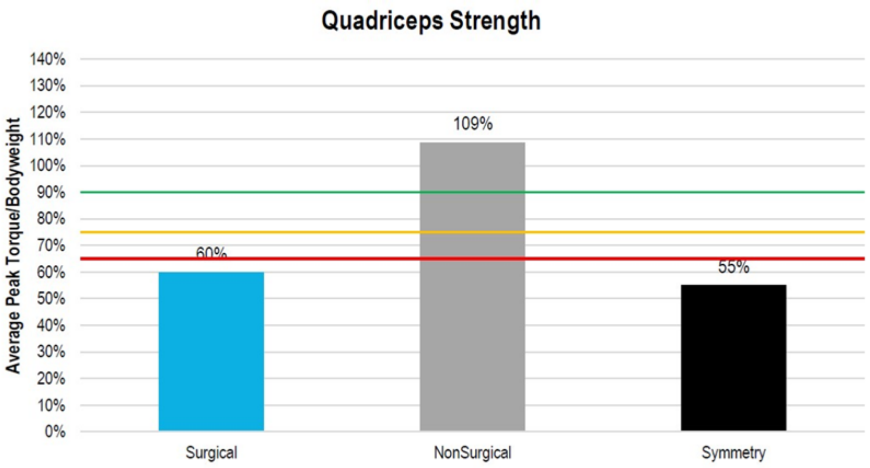


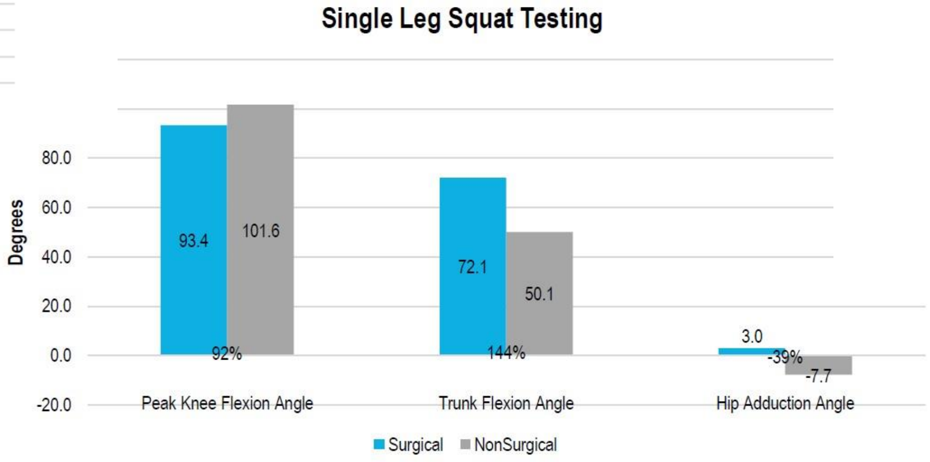
COORDINATION: SINGLE LEG LANDING MECHANICS



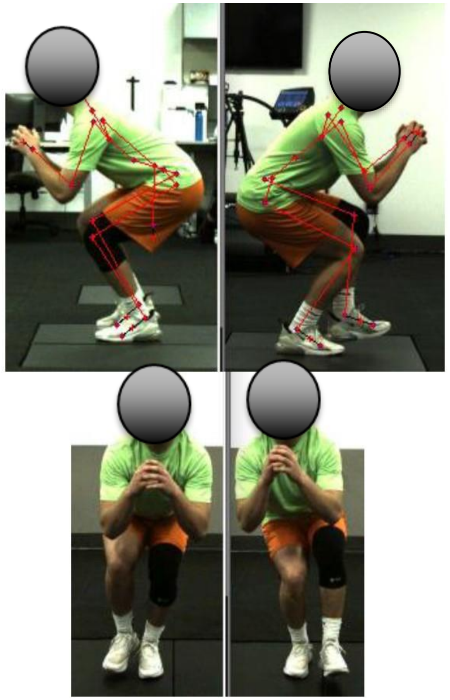
BIOMECHANICAL ASSESSMENT: BASELINE (MONTH 3-4)

- L ACLR, BTB-Auto, LMR, MMR, DOS: 9/23/22, Returning To Baseball (Goal: 5/1/23)
- DOT: 1/12/23 (4 Months)





Surgical at Peak Knee Flexion



Non-Surgical at Peak Knee Flexion

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PRESCRIBING THE RIGHT STIMULUS:

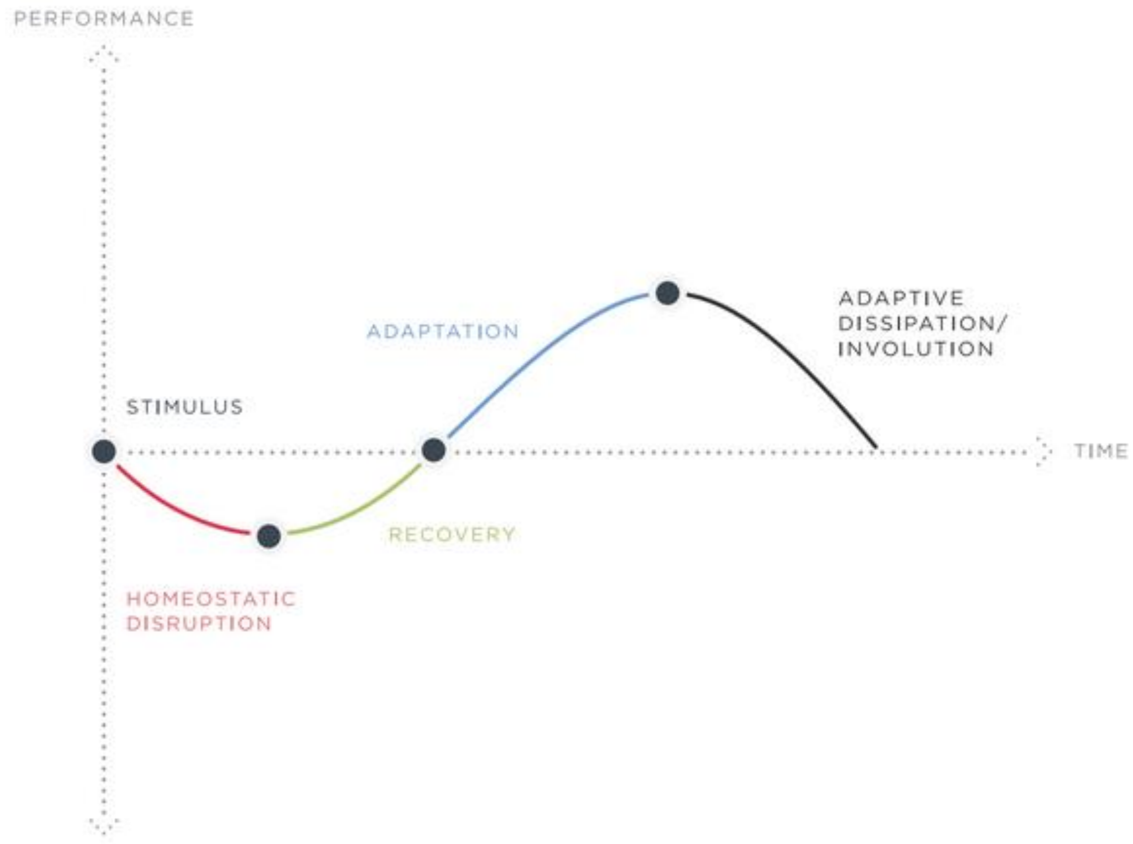


Figure 8: Stimulus-Recovery-Adaptation Curve

- Stimulus can be divided in 5 subcategories:
  - Volume/Asymmetrical Loading Scheme
    - Sets and Reps
  - Load
    - Body Weight, External Resistance
  - Intensity of the Load
    - % Max, RPE, Metabolic Thresholds
  - Tempo of the Exercises
    - Isometric, Eccentric, Concentric, Isotonic
  - Frequency
    - Completed How Many Times/Week

PROGRAMMING QUADRICEPS LOADING - VOLUME & INTENSITY

Work Capacity→ Hypertrophy→ Strength

TABLE 15.9

Load and Repetition Assignments Based on the Training Goal

Training goal	Load (%1RM)	Goal repetitions
*Strength	≥85	≤6
†Power:		
Single-effort event	80-90	1-2
Multiple-effort event	75-85	3-5
Hypertrophy	67-85	6-12
Muscular endurance	≤67	≥12

*These RM loading assignments for muscular strength training apply only to core exercises; assistance exercises should be limited to loads not heavier than an 8RM (6).

†The load and repetition assignments shown for power in this table are *not consistent* with the %1RM–repetition relationship. On average, loads equaling about 80% of the 1RM apply to the two- to five-repetition range. Refer to the discussion of assigning percentages of the 1RM for power training on page 400 for further explanation.

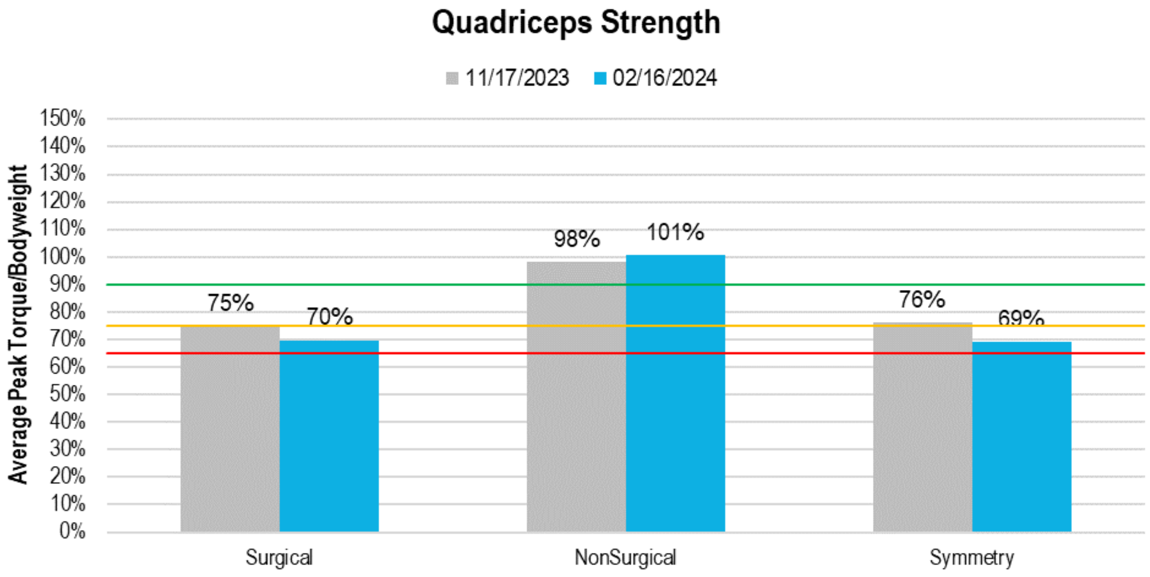
Phase 1 (Months 3-4)	Phase 2 (Months 4-5)	Phase 3 (Months 5-8)
Tendon Robustness	Work Capacity/Hypertrophy	Strength
LONG DURATION ISOMETRICS	VOLUME	INCREASED TIME UNDER TENSION
3-6 sets of 60 sec Isometric	3-4 Sets to Failure 15-20reps	3-4 sets of 5-6 reps Heavy Eccentrics
Add Load once 60 sec can be achieved	• If 20 achieved, Add Weight, • If 15, Take off weight • Goal is to fail around 17	RPE 7-9/10 Rep Tempo: 4-5sec ECC

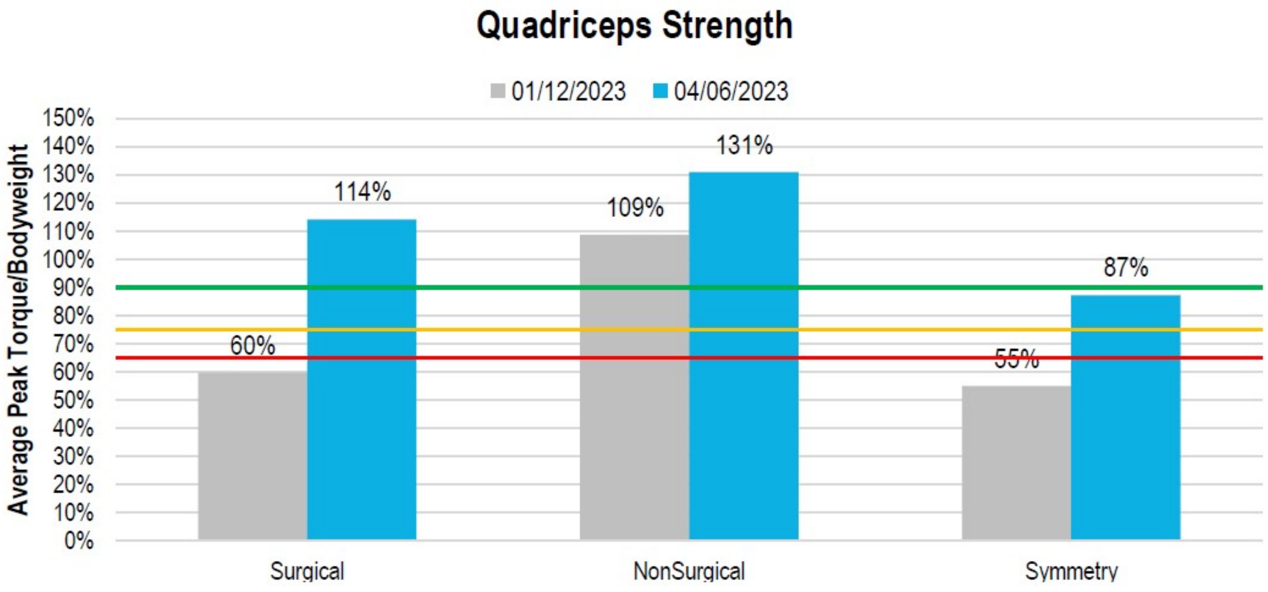
WHAT IS AN ASYMMETRICAL LOADING SCHEME?

- Asymmetrical Loading Schemes help to ensure we are providing a **Consistent, Predictable Overload!!**
  - **Clinical Observation:** An early emphasis on surgical limb overload has been correlated to correct asymmetries and result in a quicker RTS.

Asymmetrical Loading Scheme Recommendations

LSI %	<80%	80-87%	88-94%	95%<
Volume	4:1	4:2	4:3	Even





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INTEGRATING EARLY PHASE PLYOMETRICS:

- **Clinical Recommendations**
  - Joint Effusion < Trace
  - Knee ROM WNL Bilaterally
  - LSI > 70%
  - Surgical Limb Relative Strength > 55%

Plyometric Exposure Progression

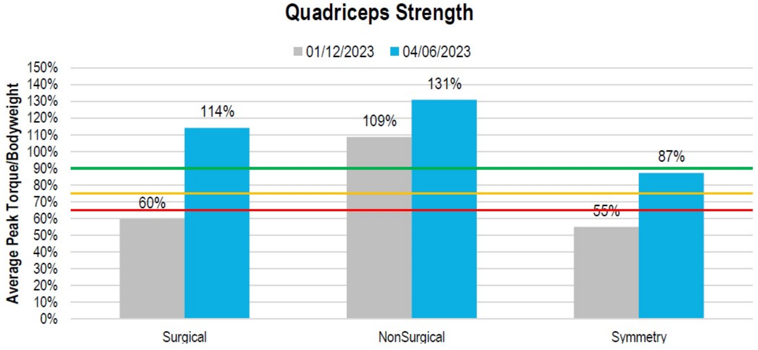
DL/SL Eccentric Absorption	Push-to-Base Decelerations	DL Concentric Development	Linear Jogging	DL Linear/Lateral Plyos (50%)	Jogging Decelerations	DL Linear/Lateral Plyos (75%)	SL Concentric Development

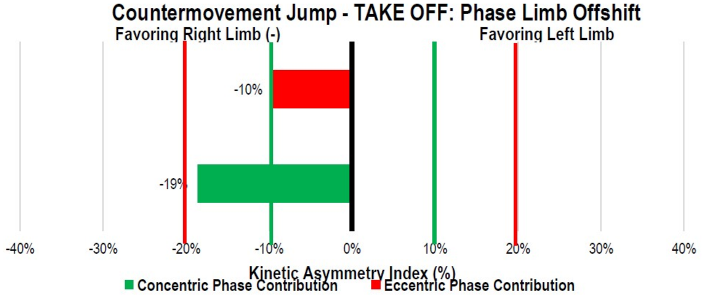
BIOMECHANICAL ASSESSMENT: PROGRESS (MONTH 6-7)

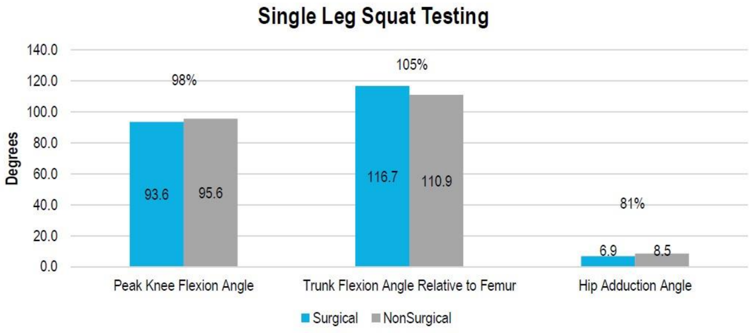
- L ACLR, BTB-Auto, LMR, MMR, DOS: 9/23/22, Returning To Baseball (Goal: 5/1/23)
- DOT: 4/6/23 (7 Months)

Psychological Readiness *ACL-RSI*	
Date	*04/06/2023*
Current Score	89%

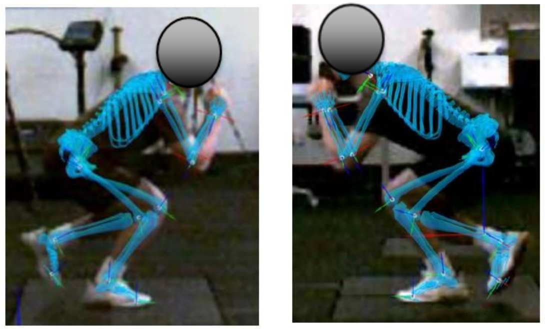
High values >76%; Low Values <65%



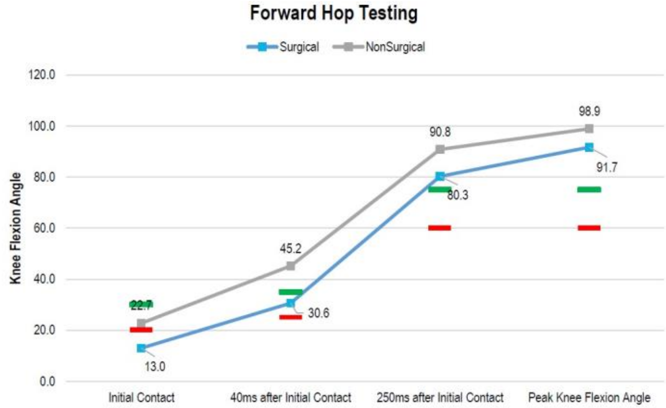




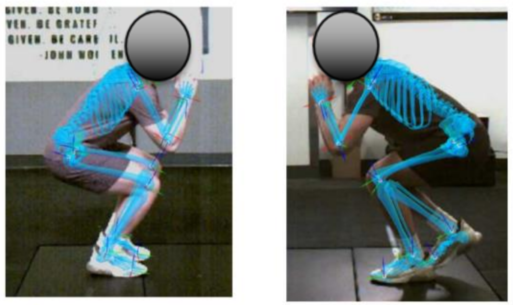
Single Leg Squat at Peak Knee Flexion



Non-Surgical Surgical



Single Leg Forward Hop at Peak Knee Flexion



Non-Surgical Surgial

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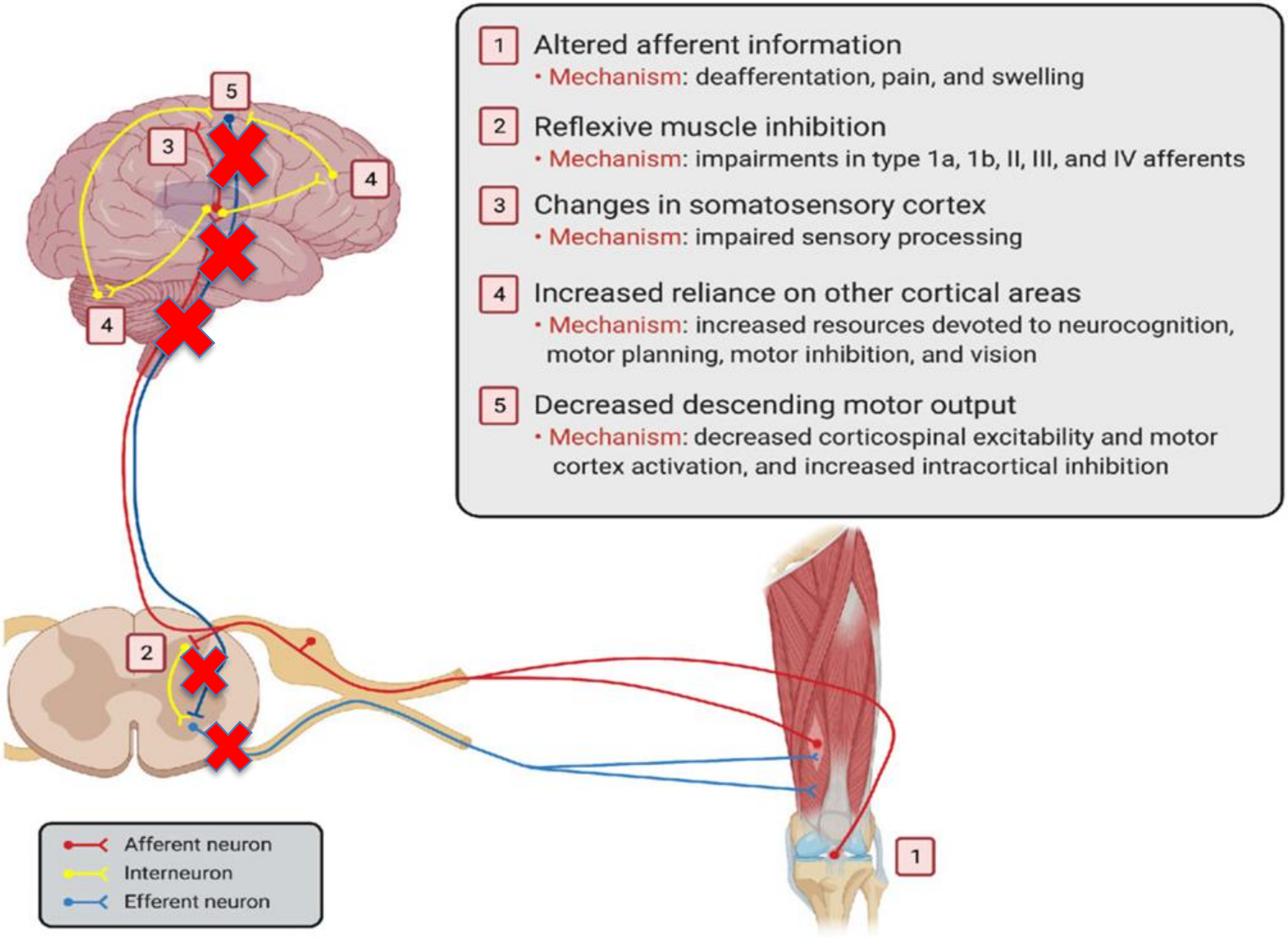
ARTHROGENIC MUSCE INHIBITION (AMI) AND NEUROLOGICAL IMPLICATIIONS

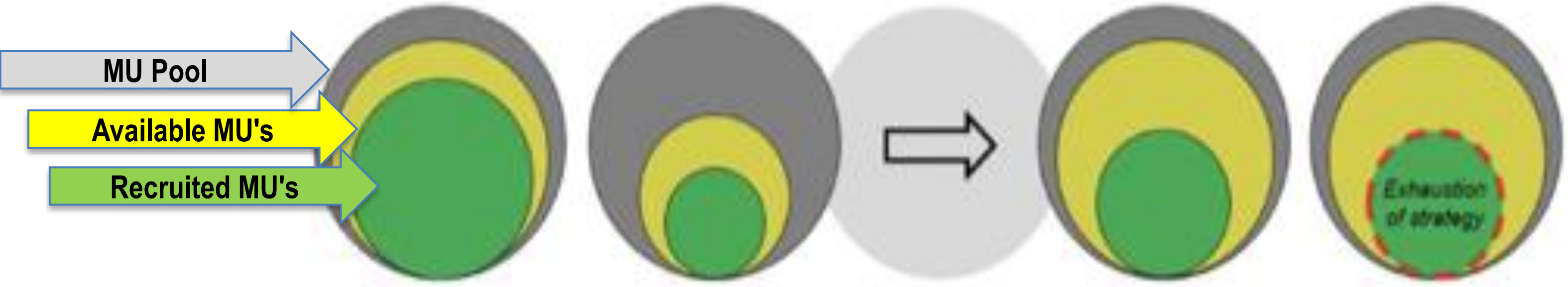
ARTHROGENIC MUSCE INHIBITION (AMI) AND NEUROLOGICAL IMPLICATIIONS

AMI Limits force production

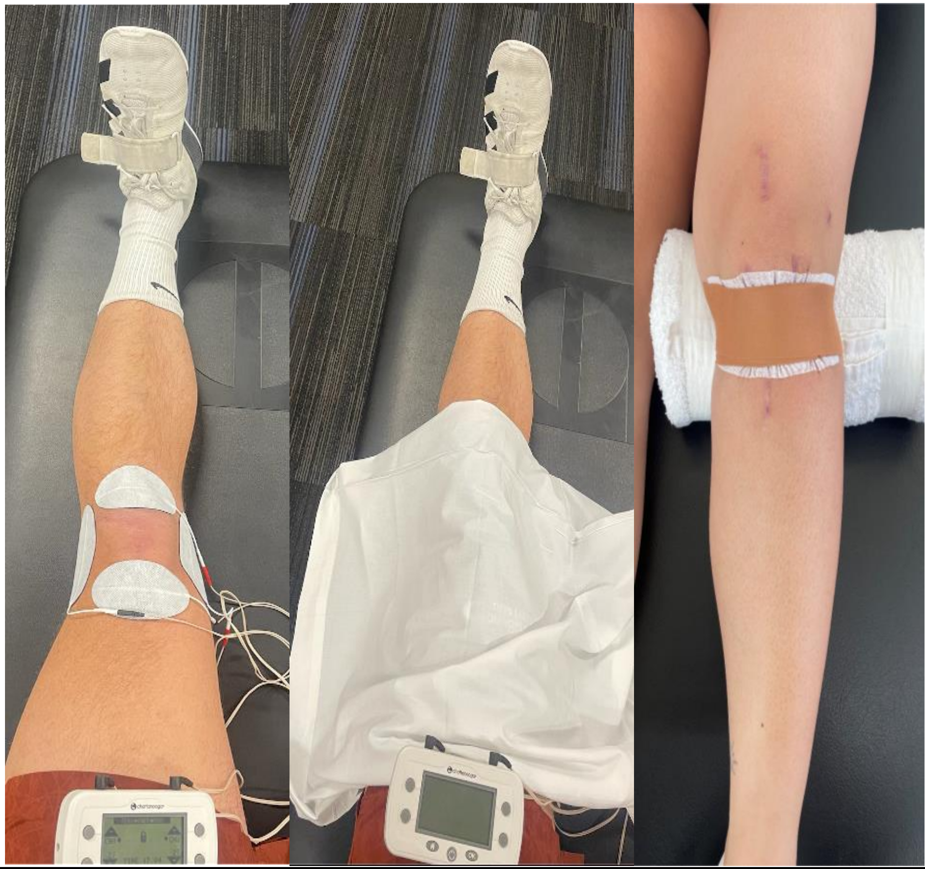
- Decreased descending motor output from higher brain centers
- Increased **sensory** signaling impairs the ability to recruit motor neurons and the muscle fibers they innervate.



DECREASED MOTOR UNIT RECRUITMENT LEADS TO DECREASED FORCE PRODUCTION



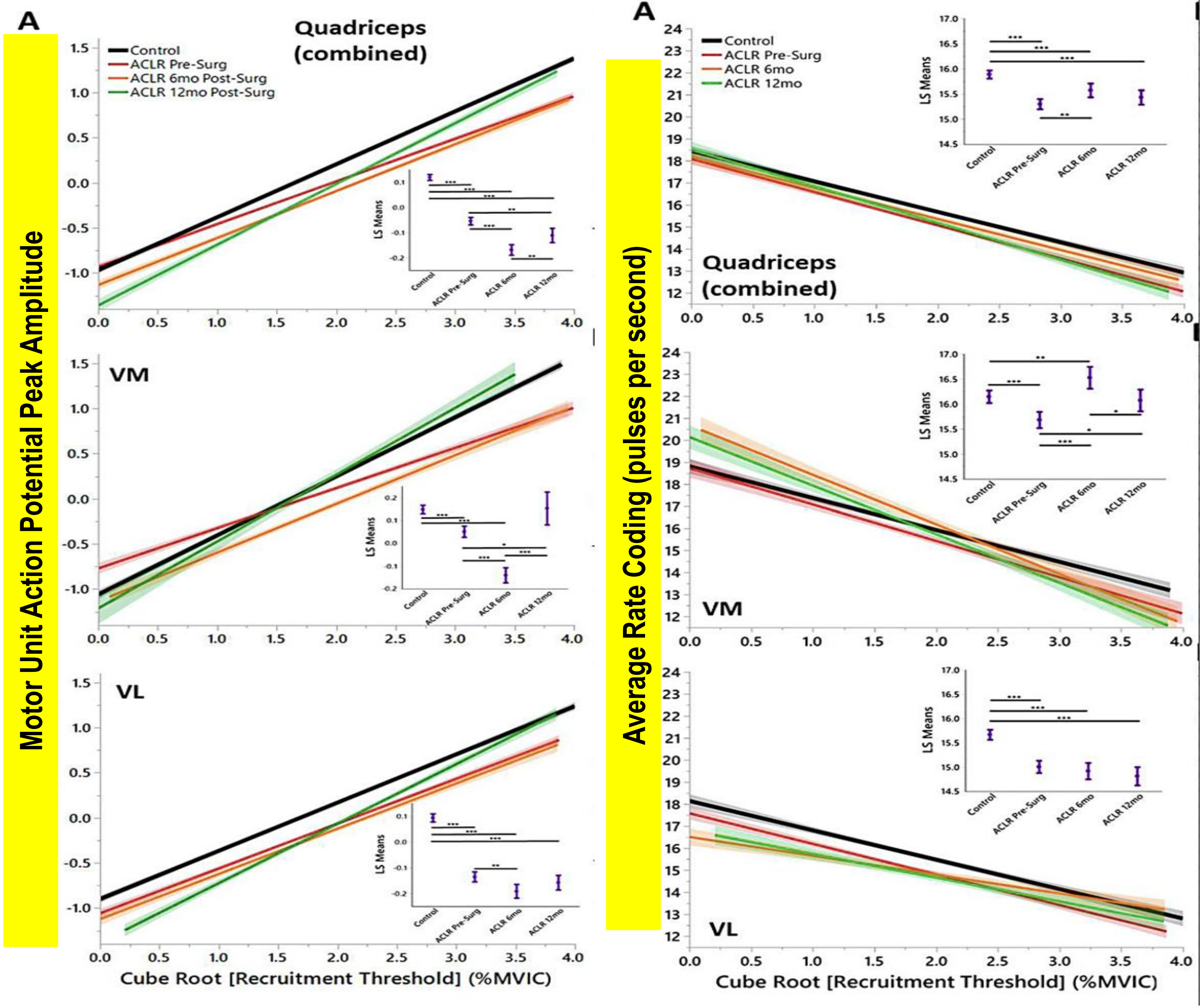
	Healthy	Acute presurgery to 6-wk postsurgery	Rehabilitation 0–6 mo	Physician clearance 6 mo	Return-to-sport 6 mo
Motor neuron behavior	Many available Many recruited *High variability*	Less available Less recruited *No variability*		Many available Less recruited *Low variability*	Many available Less recruited *Low variability*
Clinical manifestation		Weakness Muscle inhibition Poor motor control		Weak, but functional Muscle inhibition Decreased motor control *Compensated system*	*Low variability under high demand, leads to exhaustion of compensated system* *High injury risk*
Total motor neuron pool		Available motor neurons		Recruited motor neurons	



ARTHROGENIC MUSCLE INHIBITION MANIFESTS IN THIGH MUSCULATURE MOTOR UNIT CHARACTERISTICS AFTER ANTERIOR CRUCIATE LIGAMENT INJURY (SCHILATY ET AL., 2022)

Rate Coding: Increased at lower recruitment thresholds and decreased at higher recruitment thresholds

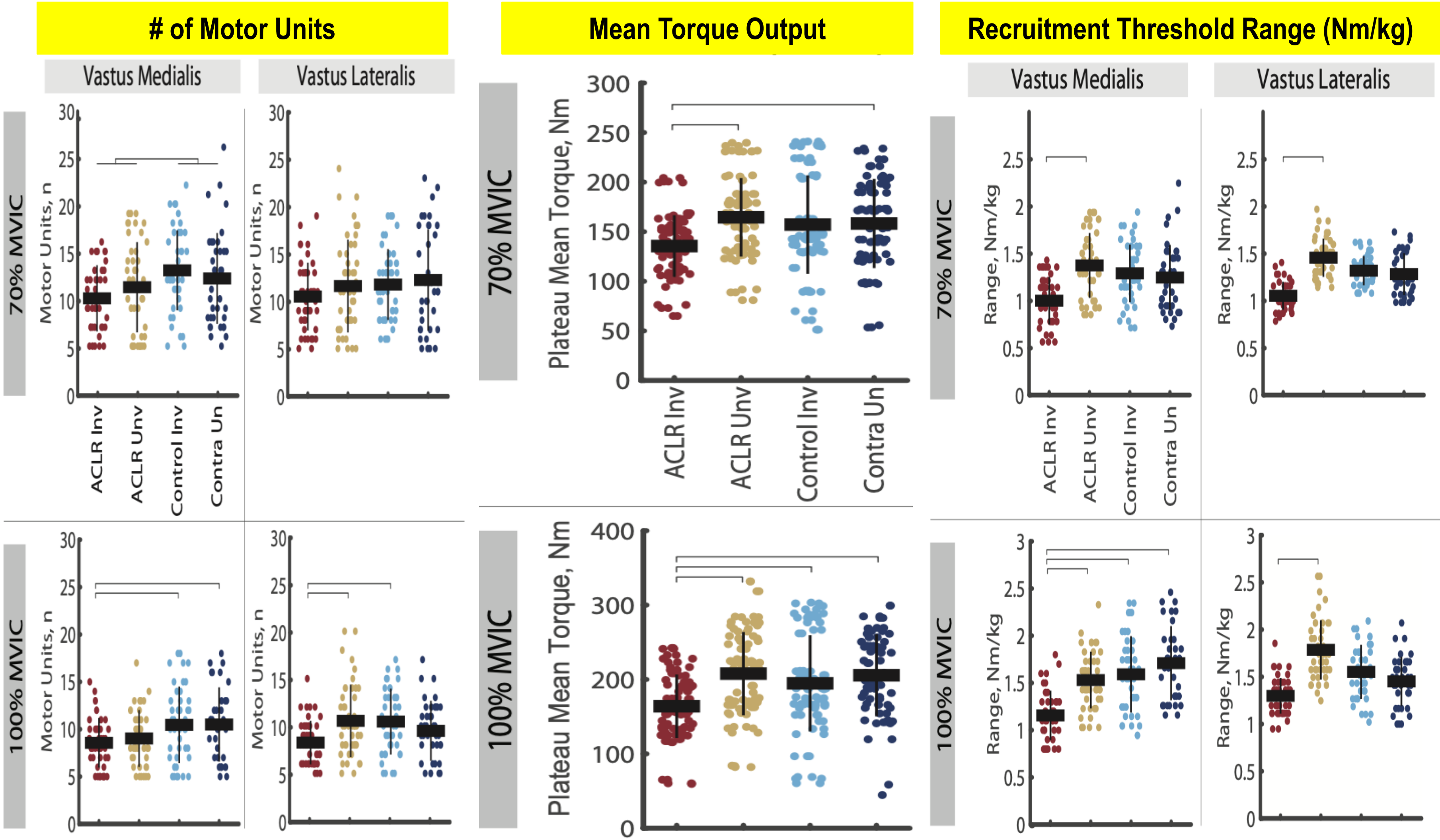
MUAP: Decreased in both low and high recruitment thresholds



NEURAL DRIVE AND MOTOR UNIT CHARACTERISTICS AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION: IMPLICATIONS FOR QUADRICEPS WEAKNESS (SHERMAN ET AL., 2023)

1) Less available MU's at submaximal and maximal intensities

2) Decreased force output at submaximal and maximal intensities



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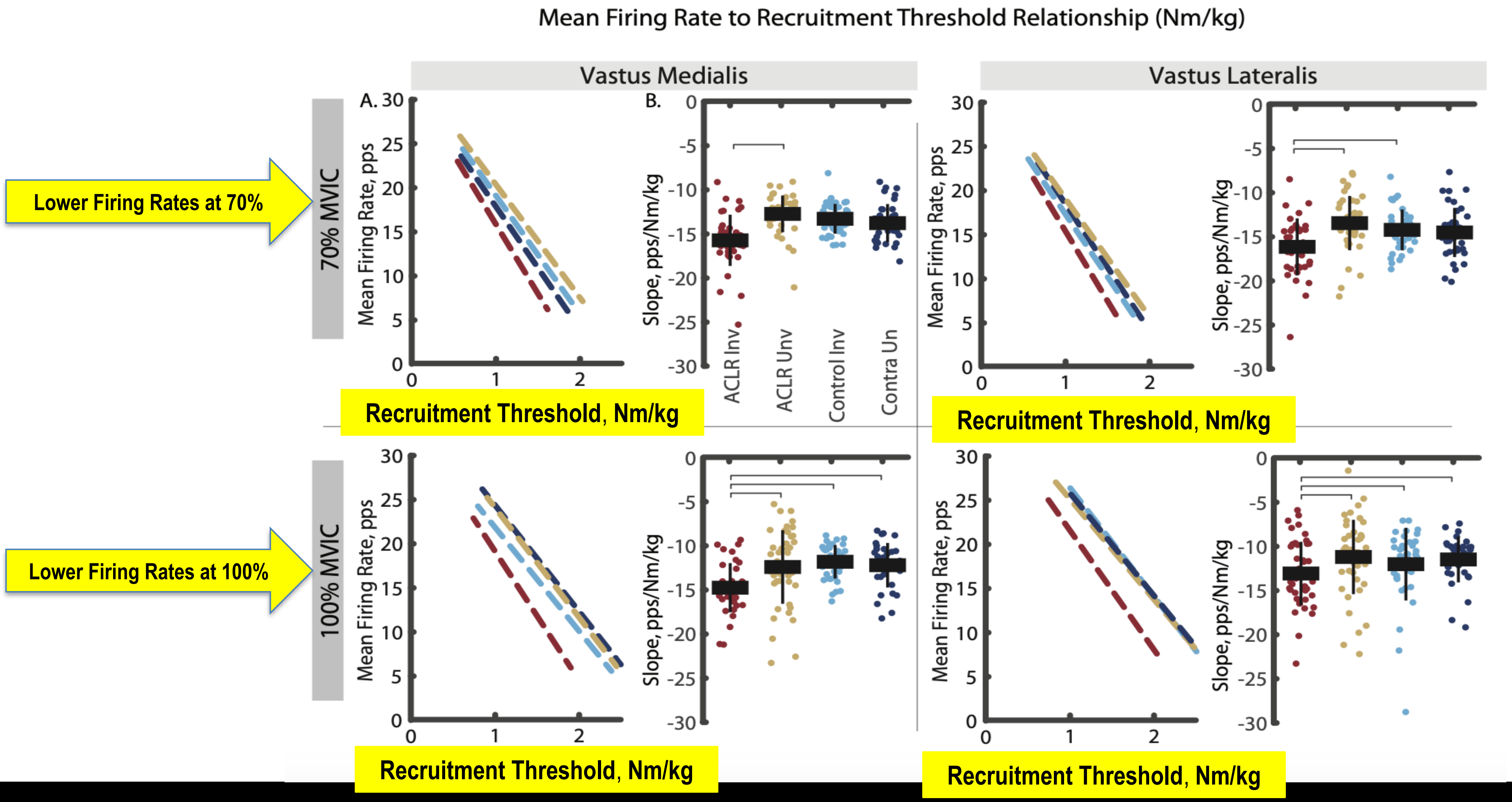
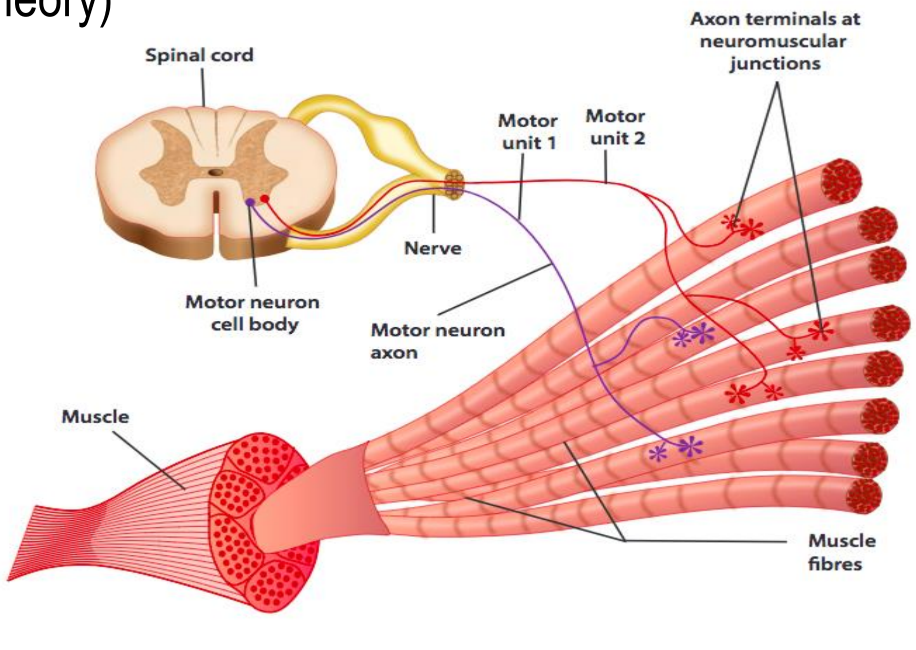


DECREASED MOTOR UNIT RECRUITMENT LEADS TO DECREASED FORCE PRODUCTION

Problem

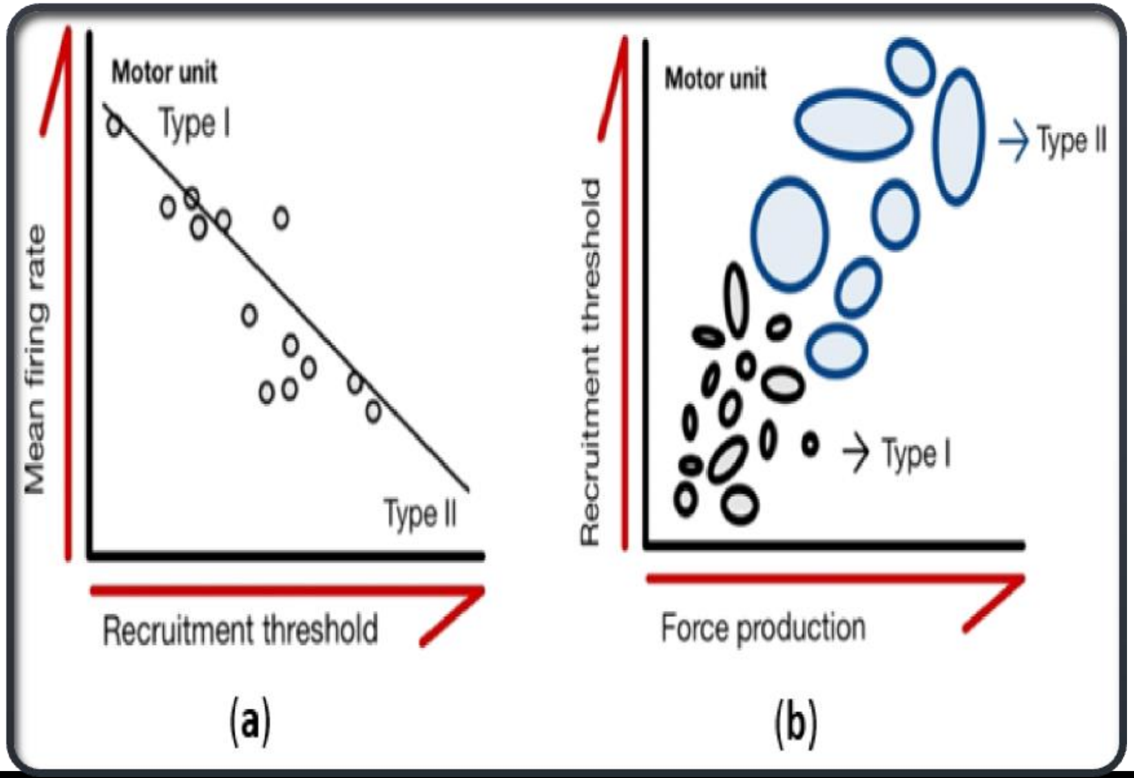
1) High Threshold MU's are innervated by type II muscle fibers
2) AMI + Lack of Stimulation result leads to ***Denervation/Atrophy*** to quadriceps muscle (theory)



Axon of motor neurons extend from the spinal cord to the muscle. There each axon divides into a number of axon terminals that form neromuscular junctions with muscle fibers scattered throughout the muscle.

Goal

1) Promote Hypertrophy/Strength by regulating MU Recruitment with resistance training



ACL GRAFT STRAIN AND EXERCISE SELECTION

GRAFT FAILURE AS A RESULT OF PROBLEMATIC HEALING (CHEN, 2009)

Likelihood
- .07-14%
- May be as high as 24.4%

Most comment rupture
- 1) Proximal
- 2) Mid Substance

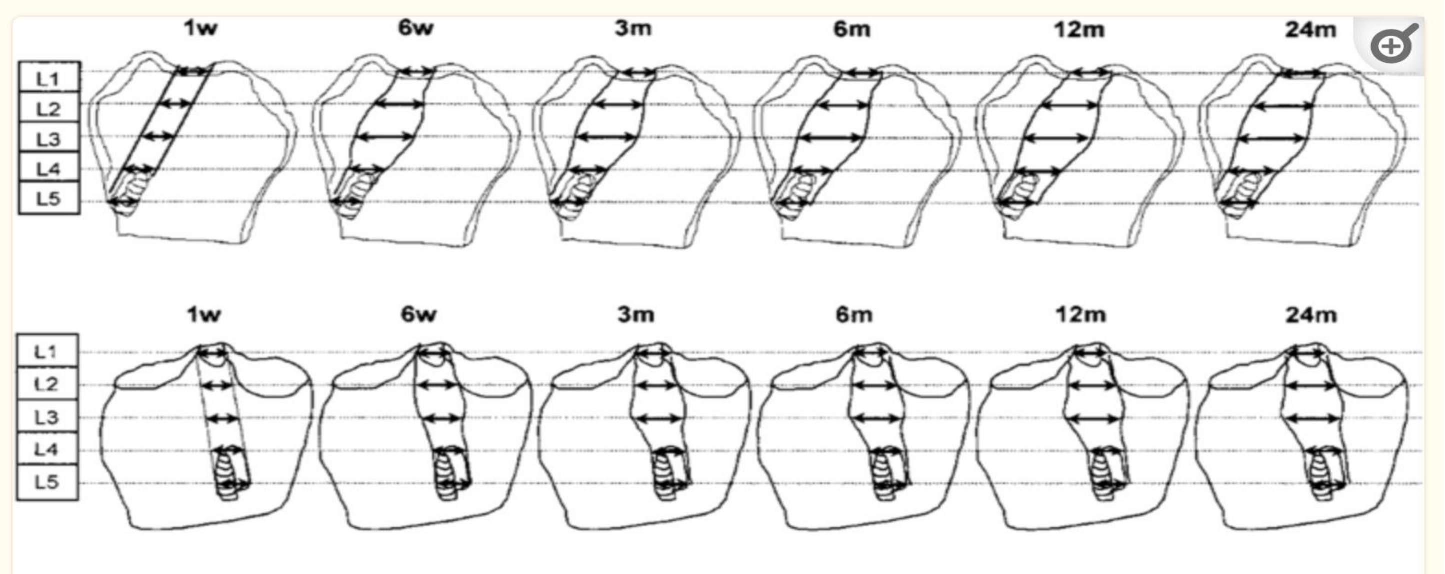
Mechanisms
- 1) Surgical Technique
- 2) Graft Incorporation
- 3) Trauma

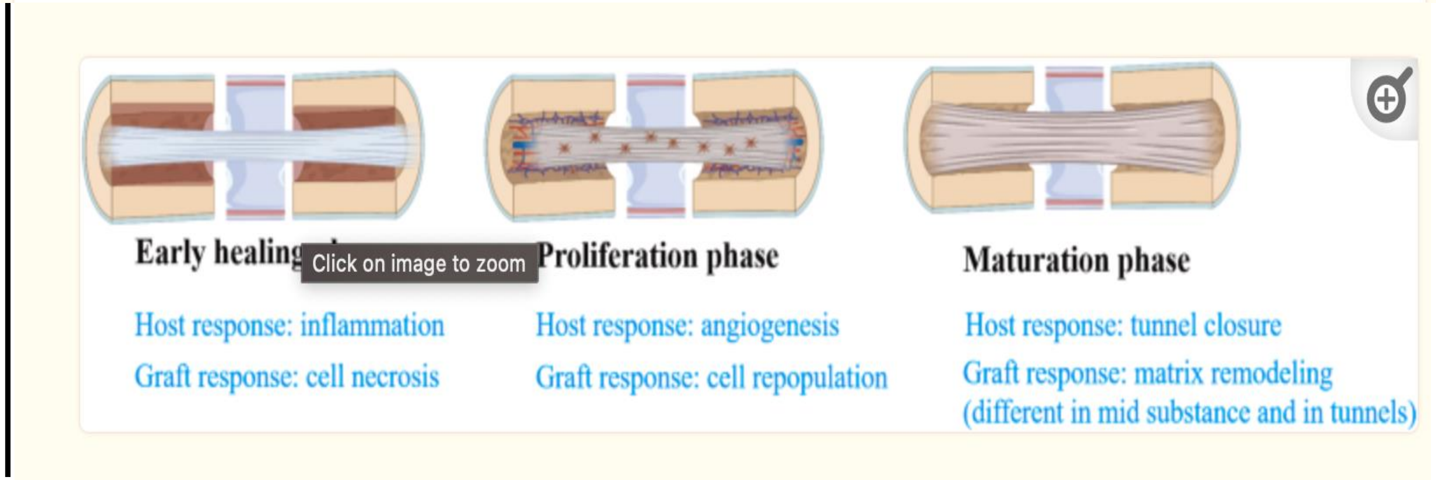
Early
- 0-3 months **Roughgraff et al. (1993)**
- 0-5 months **Abe et al. (1993)**
- 3-6 months **Falconiero et al. (1998)**
- 6-12 months **Sanchez et al. (2010)**

Remodeling
- 3-10 months **Roughgraff et al. (1993)**
- 5-9 months **Abe et al. (1993)**
- 6-12 months **Falconiero et al. (1998)**
- 12-18 months **Sanchez et al. (2010)**

Maturation
- 10-36 months **Roughgraff et al. (1993)**
- 9-50 months **Abe et al. (1993)**
- 12-50 months **Falconiero et al. (1998)**
- 18-24 months **Sanchez et al. (2010)**

GRAFT FAILURE AS A RESULT OF PROBLEMATIC HEALING (CHEN, 2009)

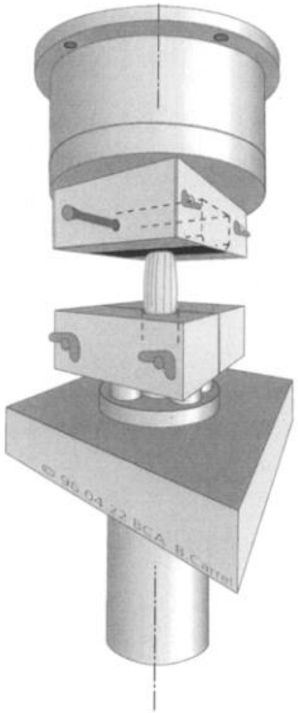




TRAINING HAUS

BONE-TENDON-BONE AND QUAD TENDON TENSILE CAPACITY (STÄUBLI ET AL., 1996)

Fig. 2 Osteo-TL-Clamp *(above)* and cryogenic fixation devices *(below)* fixed to the loadcell and to the actuators of the materials testing machine. The Osteo-TL-Clamp consists of a rectangular chamber filled with a low melting point metal fixing the proximal or distal half of the patella including full-thickness attachment of the QT and PL, respectively. The cryogenic fixation device includes the central containment chamber. Cooling the mantle of the cryofixation device in liquid nitrogen creates an ice block as the containment chamber is filled with water. The free QT and/or PL ends are thus firmly fixed to the actuators of the materials testing machine [8]



	QT-B complex	B-PL complex	*P* value
Unconditioned	(*n* = 7)	(*n* = 7)	
Ultimate load (N)	2173 ± 618	1953 ± 325	0.4275 NS
Displacement at ultimate load (mm)	5.9 ± 1.2	4.7 ± 1.2	0.0729 NS
Stiffness at 200 N (N/mm)	312.9 ± 49.6	423.4 ± 66.2	0.0012*
Stiffness at 800 N (N/mm)	474.9 ± 82.5	544.5 ± 113.3	0.3567 NS
Energy to failure (J)	6.7 ± 3.3	5.6 ± 1.9	0.4536 NS
Total energy (J)	9.0 ± 3.3	9.6 ± 3.0	0.7270 NS
Preconditioned	(*n* = 8)	(*n* = 7)	
Ultimate load (N)	2353 ± 495	2376 ± 152	0.7687 NS
Displacement at ultimate load (mm)	5.6 ± 0.8	4.4 ± 1.1	0.0372*
Stiffness at 200 N (N/mm)	325.6 ± 70.7	621.1 ± 121.8	0.00002*
Stiffness at 800 N (N/mm)	569.5 ± 108.5	904.1 ± 148.1	0.0002*
Energy to failure (J)	6.4 ± 1.5	6.2 ± 1.8	0.9339 NS
Total energy (J)	9.7 ± 1.7	10.8 ± 2.4	0.3915 NS

GRAFT STRAIN AND TENSILE FORCES FOR WEIGHT BEARING AND NON-WEIGHT BEARING EXERCISES AFT
ACL RECONSTRUCTION: A GUIDE TO EXERCISE SELECTION (ESCAMILLA ET AL., 2012)

Author	Exercise	Peak ACL Force (N)	Knee Flexion Angle (°)
Toutoungi et al[57]	Isokinetic seated knee extension (0°-90° of knee flexion) at 60°/s	349	35 to 40
	Isokinetic seated knee extension (0°-90° of knee flexion) at 120°/s	325	35 to 40
	Isokinetic seated knee extension (0°-90° of knee flexion) at 180°/s	254	35 to 40

GRAFT STRAIN AND TENSILE FORCES FOR WEIGHT BEARING AND NON-WEIGHT BEARING EXERCISES AFTER ACL RECONSTRUCTION: A GUIDE TO EXERCISE SELECTION (ESCAMILLA ET AL., 2012)

Non–Weight-Bearing Exercises

Author	Exercise	Anterior Shear Force (N)	Knee Flexion Angle (°)
Wilk and Andrews[61]	Dynamic seated knee extension (0°-90° of knee flexion) using 12 repetitions of maximum resistance*	248 ★	14

Weight-Bearing Exercises

Author	Exercise	Anterior Shear Force (N)	Knee Flexion Angle (°)
Wilk et al[62]	Barbell squat (0°-90° of knee flexion) using 12 repetitions of maximum resistance*	0	
	Leg press (0°-90° of knee flexion) using 12 repetitions of maximum resistance*	0	
Nagura et al[40]	Full squat (0°-140° of knee flexion) using no external resistance	66 ★	10.9
	Rising from kneeling	111 ★	40.9
	Level-ground walking	355 ★	16.8
	Stair climbing	146 ★	50.8
Pflum et al[44]	Double-foot drop landing	220 ★	33 to 48

Abbreviation: ACL, anterior cruciate ligament.
**Heaviest resistance possible that allowed the performance of 12 consecutive repetitions with proper form and technique.*

GRAFT STRAIN AND TENSILE FORCES FOR WEIGHT BEARING AND NON-WEIGHT BEARING EXERCISES AFTER ACL RECONSTRUCTION: A GUIDE TO EXERCISE SELECTION (ESCAMILLA ET AL., 2012)

Food for Thought

- Level Ground Walking: **303 (N)**
- Isokinetic Knee Extension: **254-349 (N)**
- Isometric Knee Extensions: **396 (N)**
- Isotonic 12RM Knee Extensions: **158 (N)**

Are Open Chain Knee Extensions Safe? (Forelli et al., 2023)

- OKC + CKC (n=51)
- CKC only (n=52)
- Results: Increased quadriceps strength in at 3,6, and 9 months. NO DIFFERENCE IN GRAFT LAXITY. (Patient began OKC at 4 weeks post-op).

This Not The Wild West

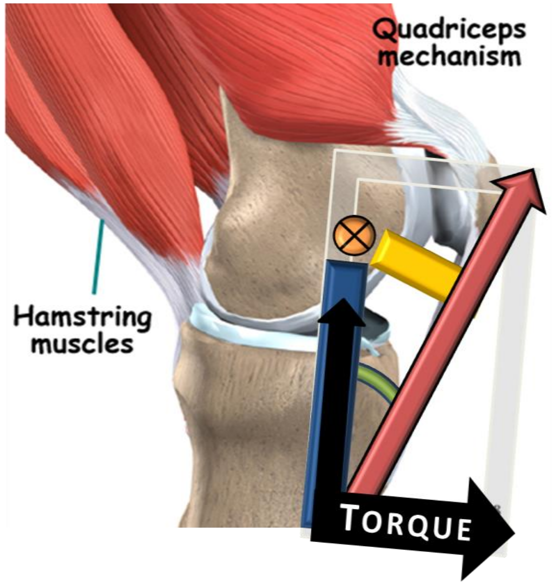
1) Respect tissue healing
2) Prioritize graft incorporation
3) A quite knee is a happy knee

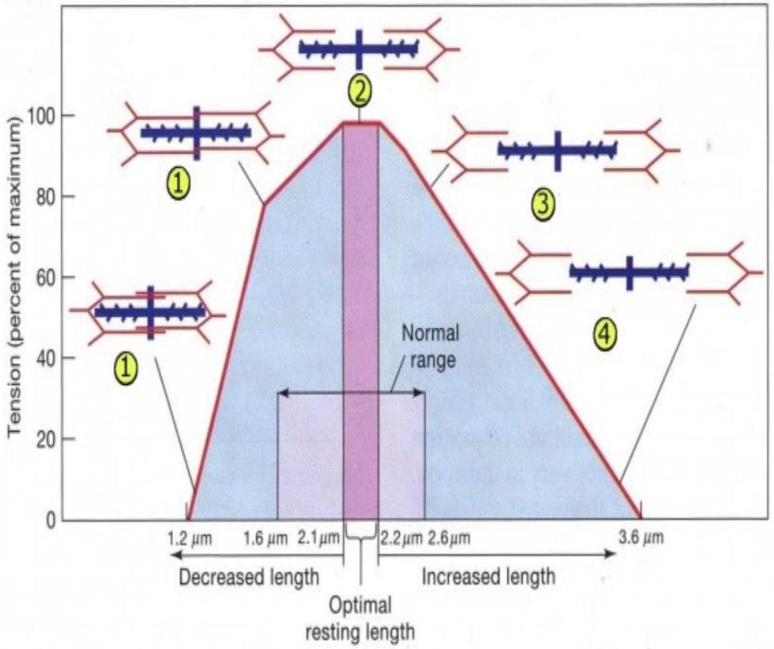
CONTROLLING RESISTANCE TRAINING VARIABLES TO ENHANCE QUADRICEPS DEVELOPMENT

Controlling Resistance Training Variables to Enhance Quadriceps Development

1) Biomechanics
2) Muscle Length
3) Intensity, Internal Focus, and Proximity to Failure
4) Load
5) Volume

Torque of Quadriceps





Closed Chain Quadriceps Biomechanics

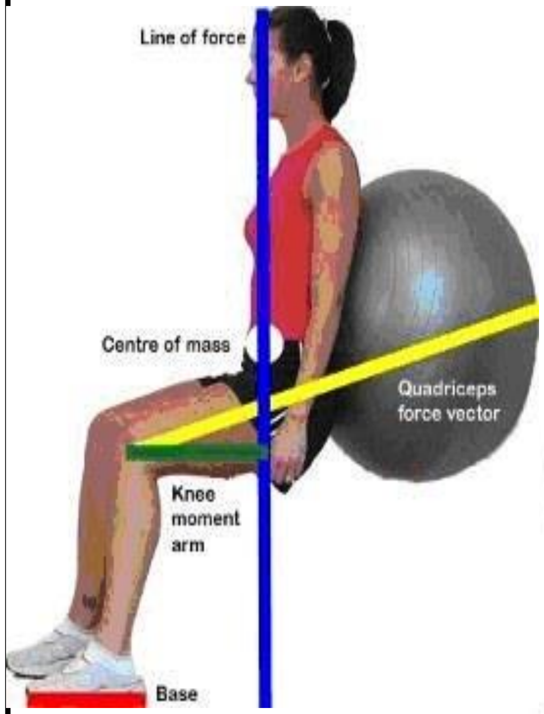
How to Create more mechanical WORK for the Quad

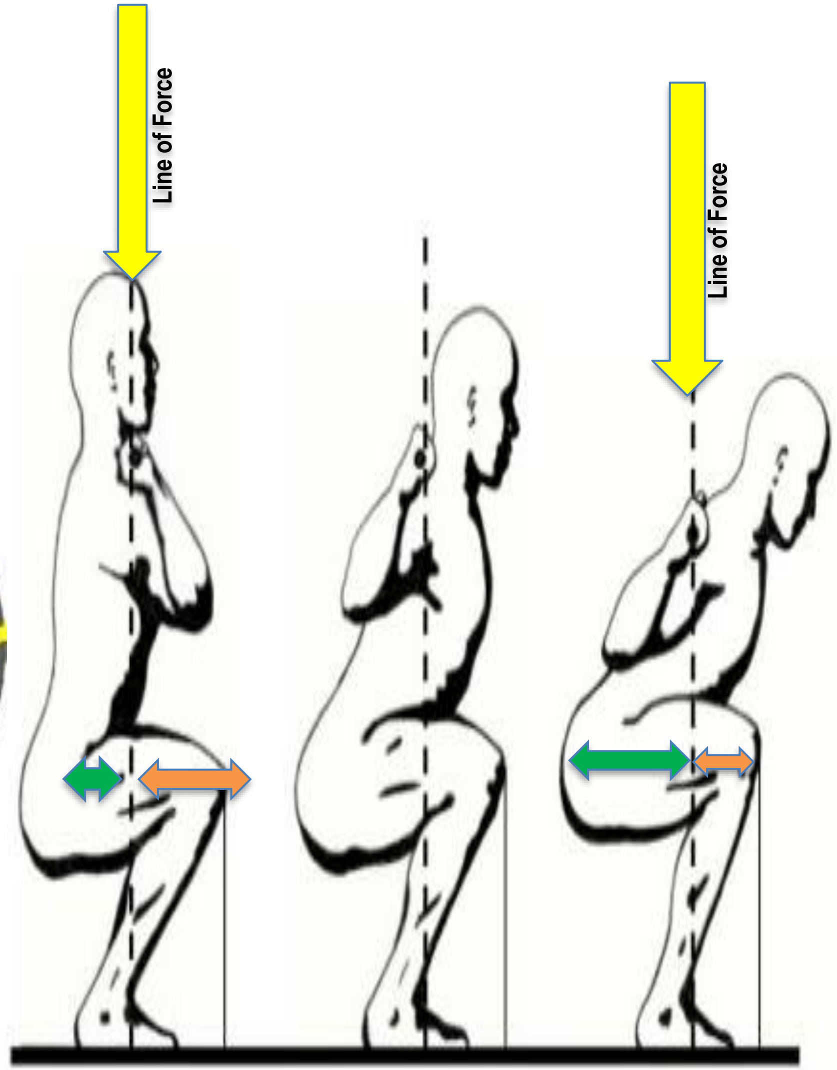
- ***External Moment Arm:*** The length between a joint axis and the line of force acting on that joint. The longer the moment arm is the more load will be applied to the joint axis through leverage.

Load Placement: Front Squat or Back Squat?

The effects of squat variations on strength and quadriceps hypertrophy adaptations in recreationally trained females (Enes et al., 2024)

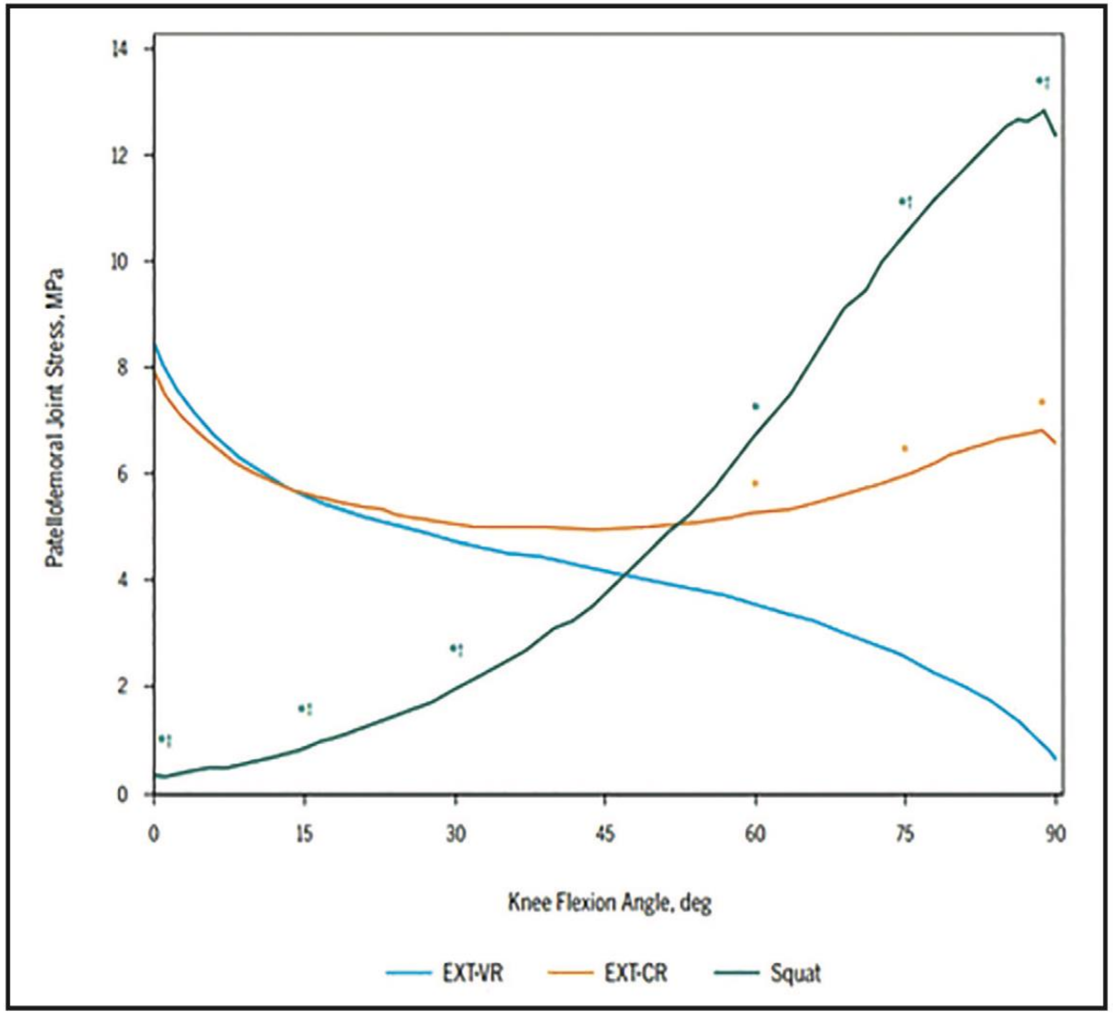
- FS trained at 25% less load and similar hypertrophy in the VL than those in the BS group





TRAINING HAUS

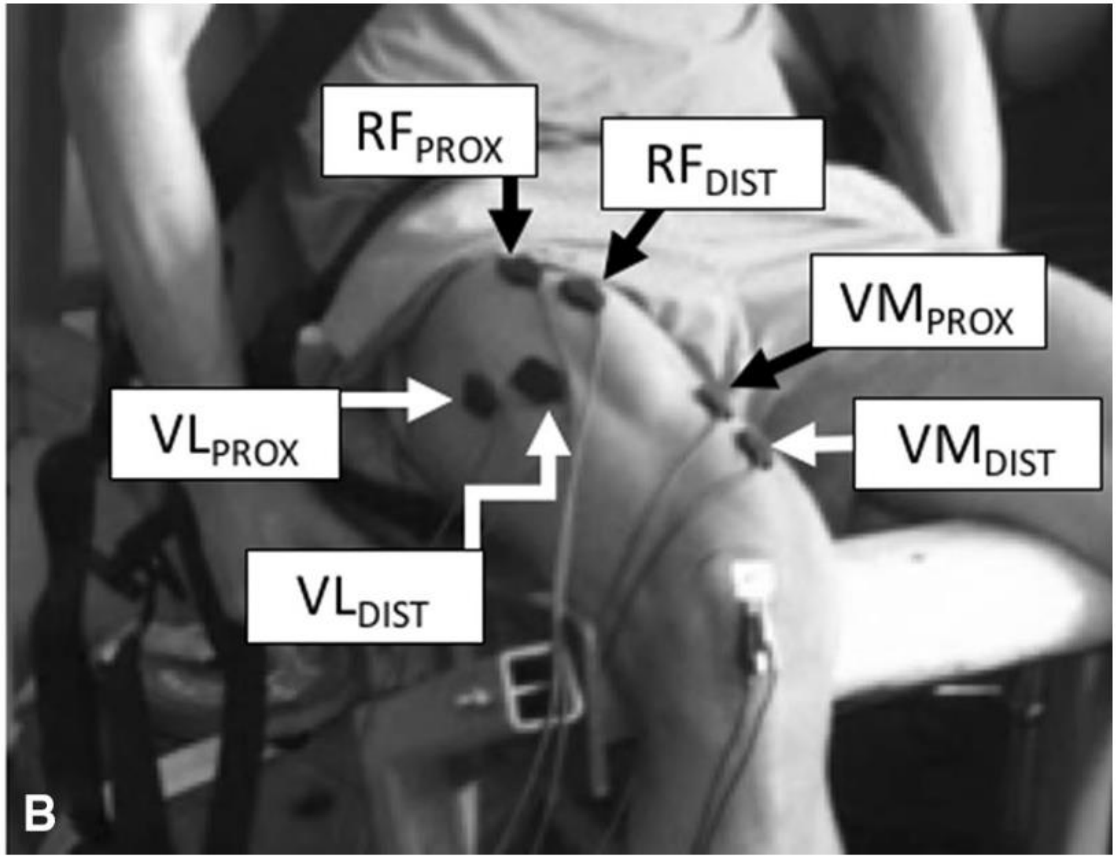
Open Chain Quadriceps Biomechanics (Willy & Meira, 2016) (Powers et al., 2014)



Surface EMG Amplitude is not a Validated Predictor of Muscle Hypertrophy (Vigotsky et al., 2022)

- **High- versus low-load resistance training:** When sets are per- formed to momentary failure, high and low loads produce similar growth despite high-loads eliciting greater sEMG amplitudes throughout the entire duration of a set

- Multi-Joint Vs. Single Joint: Squats yield lower sEMG activity and hypertrophy in the rectus femoris compared to knee extensions: ***Biomechanically this makes sense***



Resistance Training at Longer Muscle Lengths Elicits Great Muscle Hypertrophy

(Androulakis-Korakakis et al., 2023) (Wolf et al., 2023)

Training at longer muscle lengths (Even partial range in a lengthened position) likely yield a greater hypertrophic response.

The principle of specificity likely also applies to ROM, such that training should usually replicate the ROM of the outcome of interest.

- Biodex Testing (MIVC vs Isokinetic)

Controlling the eccentric and concentric portion of the movement through **full range of motion** likely yields greater muscle hypertrophy.

Table 1. Technique recommendations to maximize muscle hypertrophy.

Variable	Evidence	Maximization Recommendation
TEMPO	Moderate	A repetition tempo of 2–8 s seems to be sufficient to maximize hypertrophy, and it is currently unclear whether extending the concentric or eccentric phase of a repetition will lead to greater hypertrophy
ROM	Moderate	Employ a ROM that allows for muscles to be fully stretched
Involvement of non-target muscles	N/A	Diminish involvement by minimizing the use of external momentum when possible

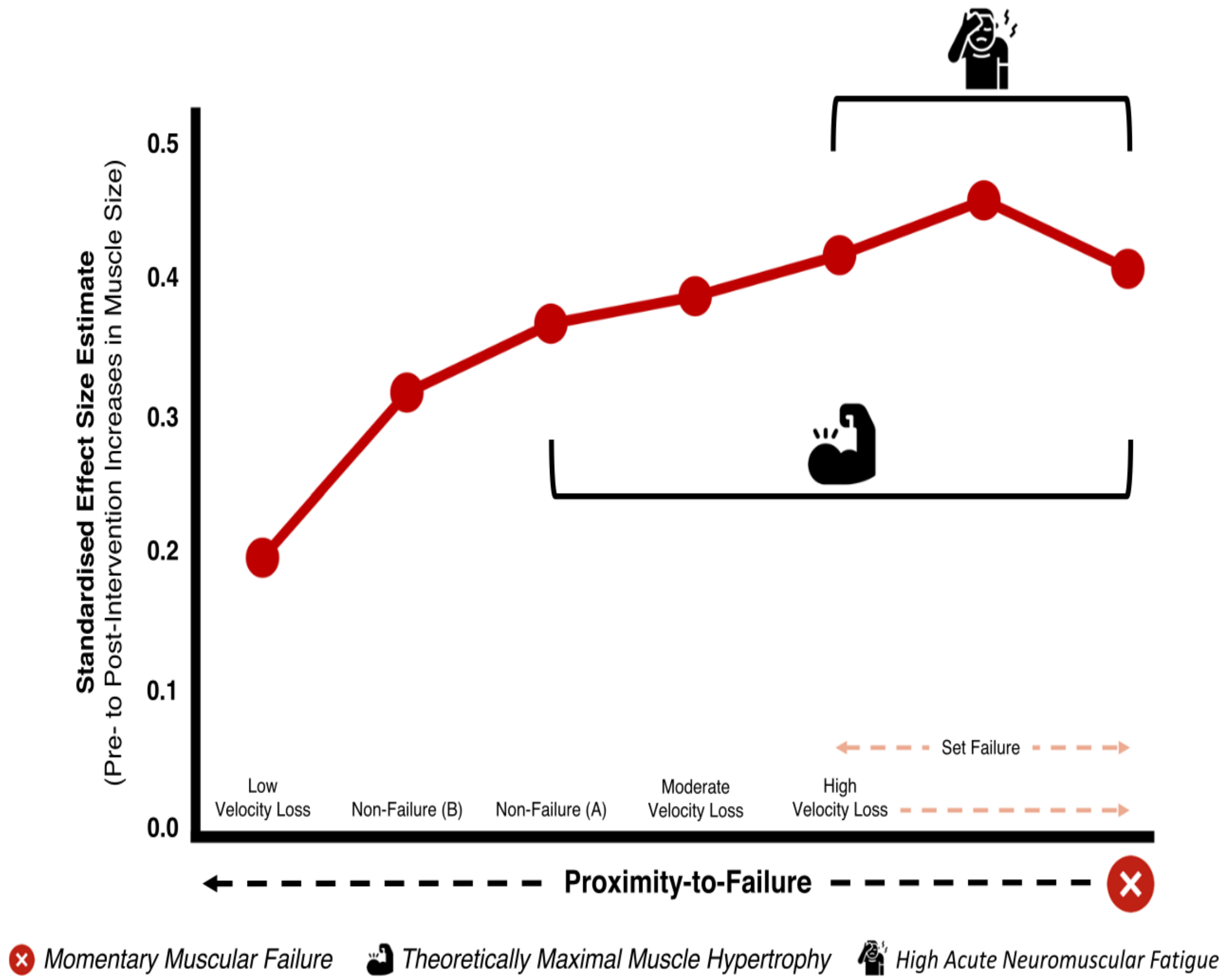
N/A, not applicable.

1) CONTROL KNEE FLEXION ANGLE / TRUNK POSITION
2) RESPECT THE LENGTH TENSION RELATIONSHIP

Perceived Intensity, Internal Focus, Proximity to Failure (Refalo et al., 2022) (Schoenfeld et al., 2021)

Skeletal muscle can be effectively stimulated to hypertrophy prior to reaching momentary muscular failure during RT, but because of methodological limitations, it is difficult to discern the proximity-to-failure that would theoretically maximize muscle hypertrophy.

Proximity to failure is key



Strength vs. Hypertrophy: Load, Volume, Intensity (Baz-Valle et al., 2022) (Schoenfeld et al., 2021)

Hypertrophy

Intensity of Effort (Volitional Fatigue / Internal Focus)
Load: >30% 1RM
Volume: 12-20 weekly sets when training each muscle group twice per week
- *This Includes both single and multi-joint movements*
- *No additional benefits of increasing training volume beyond 20 sets*

Inter-set Rest: >60 seconds

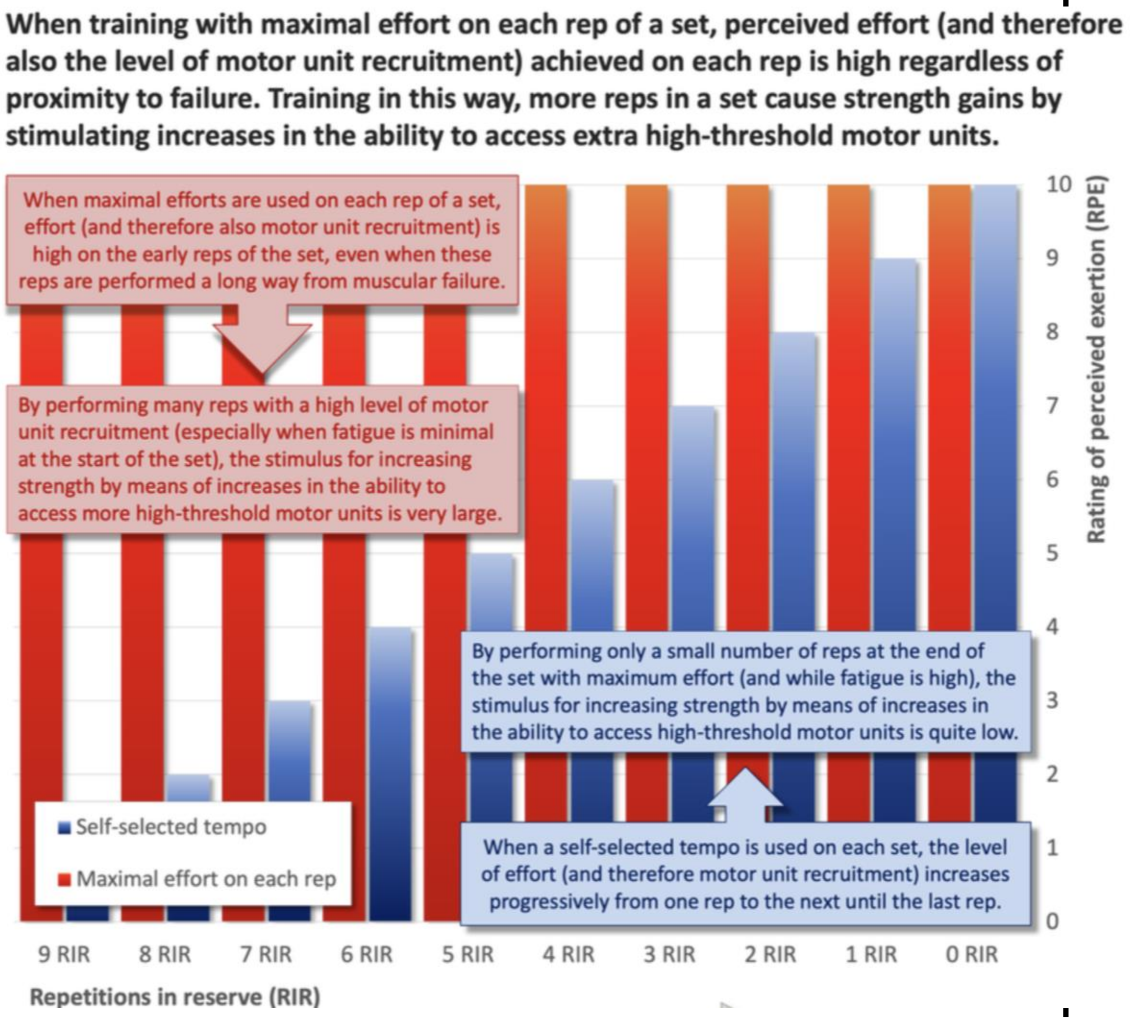
This Systematic group included studies that all performed all working sets at maximum effort (Momentary Failure) with an exception of one study that completed exercises with 2 reps in reserve

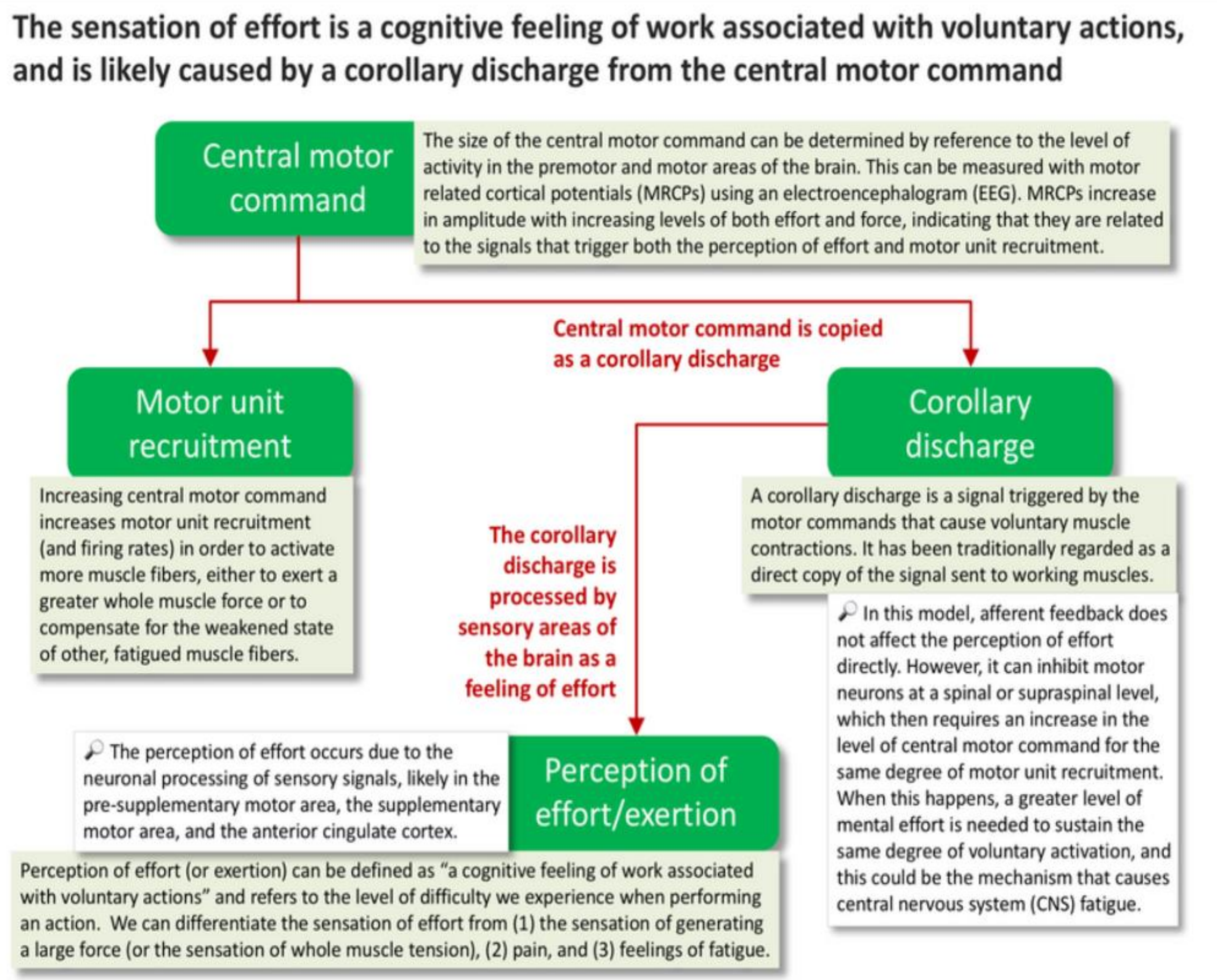
Strength

Specificity: Training for the test
Load: >85% 1RM
Volume: <15 sets/muscle/week
Inter-set rest: 2-5 minutes

Intent: How the Set is Performed Matters

Patreon. (n.d.). *RPE and RIR | Chris Beardsley*. https://www.patreon.com/posts/rpe-and-rir-58859512





Regulating Intensity

RIR VS. RPE AUTOREGULATION

RIR (REPS IN RESERVE)		RPE (RATE OF PERCEIVED EXERTION)
0	MAX EFFORT ACTIVITY	10
1	VERY HARD ACTIVITY	9
2-3	VIGOROUS ACTIVITY	7-8
4-5	MODERATE ACTIVITY	5-6
6-8	VERY LIGHT ACTIVITY	2-4
9-10	LIGHT ACTIVITY	1-2

@mack_canady

@mack_canady

Load (1 RM%)	Bench	Squat	TB Deadlift	Hang Snatch	Hang Clean	Max Exertion	Near Max Exertion		Hard Exertion		Medium Hard Exertion	
	MV (m/s)	MV (m/s)	MV (m/s)	PV (m/s)	PV (m/s)	0 Rep in Tank	1 Rep in Tank	2 Rep in Tank	3 Rep in Tank	4 Rep in Tank	5 Rep in Tank	6 Rep in Tank
100%	0.15	0.3	0.26	2.3	1.8	1						
95%	0.23	0.38	0.32	2.38	1.88	2	1					
90%	0.31	0.46	0.38	2.46	1.96	3	2	1				
85%	0.39	0.54	0.44	2.54	2.04	5	3	2	1			
80%	0.47	0.62	0.5	2.62	2.12	6	5	3	2	1		
75%	0.55	0.70	0.57	2.7	2.2	8	6	5	3	2	1	
70%	0.63	0.78	0.63	2.78	2.28	10	8	6	5	3	2	1
65%	0.71	0.86	0.69	2.86	2.36	12	10	8	6	5	3	2
60%	0.79	0.94	0.75	2.94	2.44	14	12	10	8	6	5	3
55%	0.87	1.02	0.81	3.02	2.52	16	14	12	10	8	6	5
50%	0.95	1.10	0.87	3.1	2.6	20	16	14	12	10	8	6
45%	1.03	1.18		3.18	2.68	22	18	16	14	12	10	8
40%	1.11	1.26		3.26	2.76	24	20	18	16	14	12	10
35%	1.19	1.34		3.34	2.84	26	22	20	18	16	14	12
30%	1.27	1.42		3.42	2.92	28	24	22	20	18	16	14

** Difference in velocity per 5% in 1RM, can vary between 0.07-0.09 m/s*

** When an athlete increases the MV by 0.07-0.09m/s attained with a given absolute load, performance in 1RM has improved by 5%*

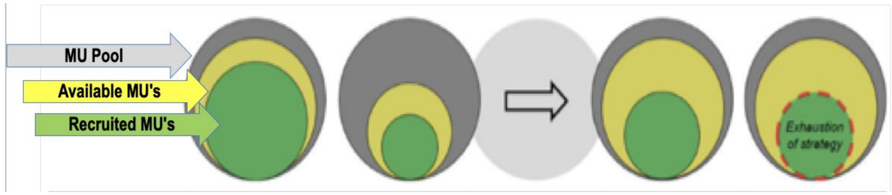
** **RESOURCE** - MOVEMENT VELOCITY AS A MEASURE OF LOADING INTENSITY INRESISTANCE TRAINING, GONZALEZ-BADILLO, SANCHEZ-MEDINA. INT J SPORTS MEDICINE. 2010, 31: 347-352*

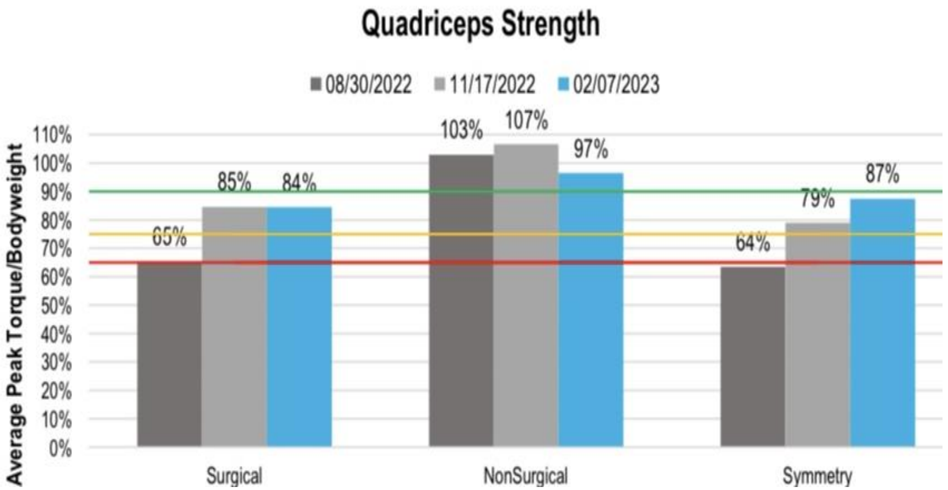
** **RESOURCE** - RESEARCHED APPLICATIONS OF VELOCITY BASED STRENGTH TRAINING Mladen Jovanović1 & Dr Eamonn P. Flanagan2. J Aust. Strength Cond. 22(2) 58-69. 2014*

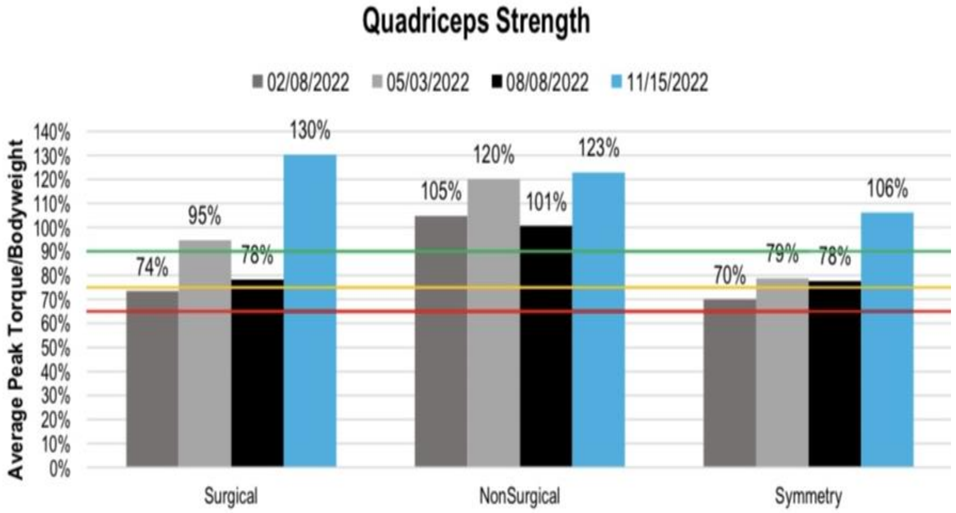
TRAINING HAUS

Why didn't these patient get

1) Decreased rate coding and MUAP, Inability to recruit higher threshold MU's
2) Reflexive Muscle Inhibition due to graft site discomfort
3) Lack of intensity/effort/Internal Focus







EXERCISE SELECTION TO MEET RTP CRITERIA

1) Biomechanics: Moment arms yield greater mechanical work

Regulate Moment Arms (Front Rack Variations) and program Knee Extensions

2) Resistance training at longer muscle lengths is likely superior to training at shorter muscle lengths when talking about hypertrophy. Strength is more specific to testing means.

Regulate knee flexion angle with squats and knee extensions to yield greater mechanical tension on the quadriceps at a controlled tempo

3) Proximity or nearness to muscular failure is likely necessary to maximize hypertrophy.

Using reps in reserve can be a good way to ensure patient understanding and compliance with prescribed intensities and rep schemes

4) Load (Hypertrophy: >30% 1RM / Strength: >85%1RM)

Hypertrophy training should be completed at a minimum of 30% or a person's relative 1RM for hypertrophy training. Load becomes more important when training for strength which is specific to the means of testing (1RM/Biodex Testing)

5) Volume: Total of 12-20 working sets per muscle group per week.

There is does not seem to be a statistically significant increase in hypertrophy after 20 workings sets/muscle group. This is still unclear water but is worth considering when workin with patient that are recovering from a knee procedure.

YIELDING ISOMETRICS: HIGH EXERTION THROUGH AFFERENT FEEDBACK

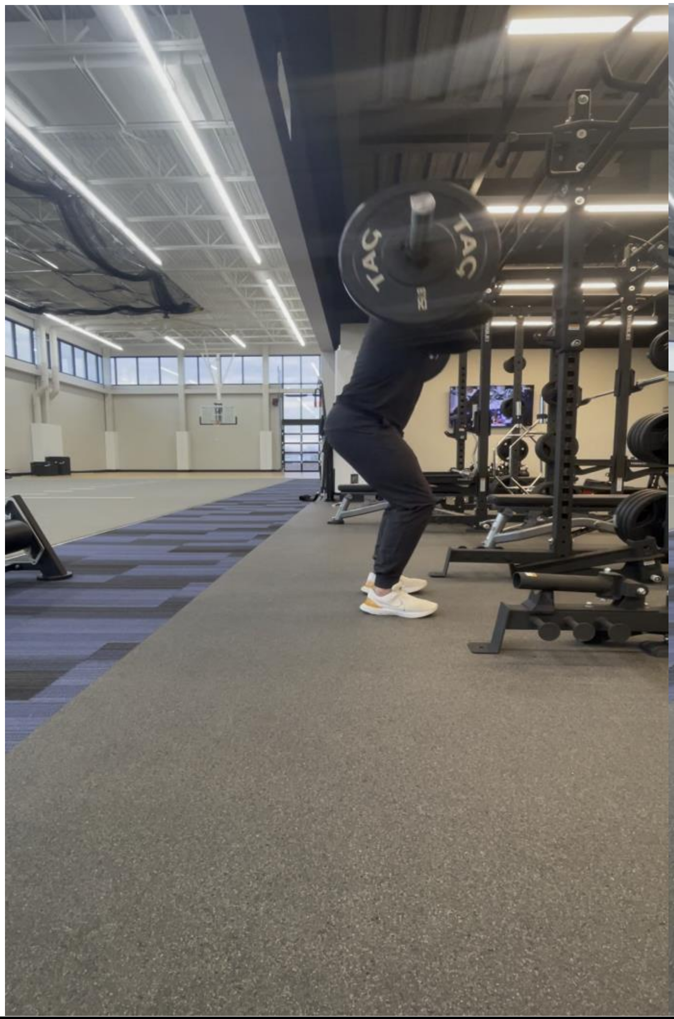
OVERCOMING ISOMETRIC: HIGH EXERTION THROUGH HIGH EFFORT (COROLLARY DISCHARGE)

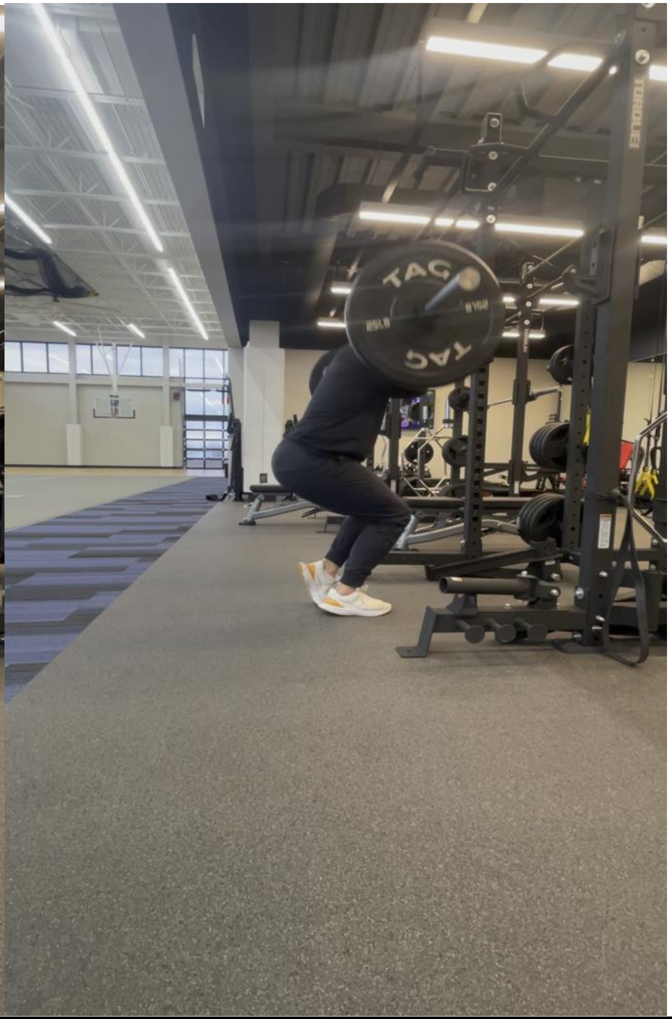
CONTROLLING PSYCHOLOGICAL AROUSAL WITH TACTILE FEEDBACK

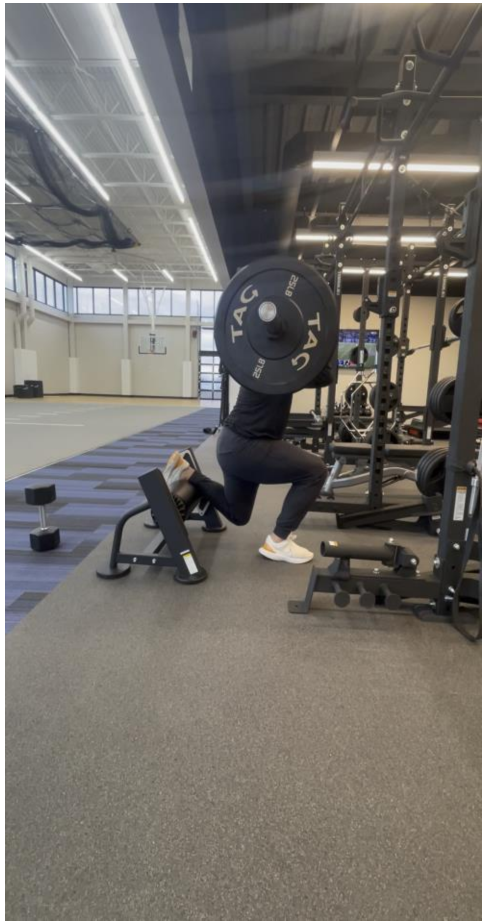
INTRODUCING EXTERNAL LOAD

SLANT BOARDS CONTROL CENTER OF MASS BY MAINTAINING A MORE UP TRUNK POSITION

CONTROLLING EFFORT AND CONCENTRIC FORCE PRODUCTION: CLUSTER SETS







ECCENTRIC CONTROL: HIGH RATE OF CHANGE IN FORCE AND JOINT POSITION

ACE STRENGTH: PHASE 1

Date of Surgery:

Quad Strength:

TWIN CITIES ORTHOPEDICS | TRAINING HAUS

ACE STRENGTH: PHASE 1

Effusion:

Range of Motion:

MONDAY | FRIDAY | FRIDAY

INTENSITY OF EFFORT IS KEY FOR HYPERTROPHY

MONDAY — Weeks 1-2

Note: Use 6" box on top of 18" box / Place TKE band around Sled and Surgical Knee

Exercise	Week	Tempo	Sets	Reps	RIR	Weight
Pinnochio Kickstand Squat	Week 1	(1-5-1-1)	3s,1ns	10	2 to 3	
Hold on Last Rep to Failure	Week 2	(1-10-1-1)	4s,1ns	6	2 to 3	
Barbell Rack Pull		1-3-1-1	3	5		

Exercise	Week	Tempo	Sets	Reps	RIR	Weight
Single Leg Hip Extension Iso on Box			3	30s		
Lateral Plank from Knee			3	30s		
Russian Hamstring Curl		3-1-1-1	3	8		
Single Leg Calf Raise on Shuttle			2s,1ns	12 to 20		
Keiser Knee Extension (100-60 deg)	Week 1		3s	12 to 20	1 to 2	
	Week 2		3s	12 to 20	1 to 2	

WEDNESDAY — Weeks 1-2

Note: Use 6" box on top of 18" box / Place TKE band around Sled and Surgical Knee

Exercise	Week	Tempo	Sets	Reps	RIR	Weight
Narrow Stance Goblet Squat on Slant Board	Week 1	(3-2-1-1)	4	8 to 10	3	
Increase Load: This is a BILATERAL movement	Week 2	(3-2-1-1)	3	12	1 to 2	
Kickstand Barbell Rack Pull		1-3-1-1	3	5		

Exercise	Week	Tempo	Sets	Reps	RIR	Weight
Single Leg CKC Clam at Wall with Knee Push on Box			3	30s		
Adductor Plank			3	30s		
Glute Ham Razor Curl			3	10		
Single Leg Calf Raise on Stair			3s,1ns	12 to 20		
Single Leg Shuttle Press (Hold Last Rep)	Week 1		3s	12 to 20		
	Week 2		3s	12 to 20		

Give What You Can Today

FRIDAY — Weeks 1-2

Note: Use 6" box on top of 18" box / Place TKE band around Sled and Surgical Knee

Exercise	Week	Tempo	Sets	Reps	RIR	Weight
Pinnocio Split Stance Squat	Week 1	(1-5-1-1	3s,1ns	8	2 to 3	
	Week 2	(1-8-1-1	4s,2ns	6	2 to 3	
Barbell Rack Pull		1-3-1-1	3	5		

Exercise	Week	Tempo	Sets	Reps	RIR	Weight
Single Leg Hip Extension Iso on Box			3	30s		
SL CKC Clam at Wall with Knee Push in Box			3	30s		
Russian Hamstring Curl			3	8		
Single Leg Calf Raise on Shuttle			3	12 to 20		
Keiser Knee Extension (100-60 deg)	Week 1		3s	12 to 20	0	
	Week 2		3s	12 to 20	0	

ACE STRENGTH: PHASE 1

Date of Surgery:

Quad Strength:

TWIN CITIES ORTHOPEDICS | TRAINING HAUS

ACE STRENGTH: PHASE 1

Effusion:

Range of Motion:

MONDAY | Wednesday | FRIDAY

INTENSITY OF EFFORT IS KEY FOR HYPERTROPHY

MONDAY — Weeks 3-4

Note: Place TKE band around Sled and Surgical Knee

Exercise	Week	Tempo	Sets	Reps	RIR	Weight
Pinnochio Kickstand Squat	Week 3	1-15-1-1	3s,1ns	4	3	
	Week 4	1-30-1-1	3s,1ns	2	3	
Reverse Step Down to March at Wall (6" box)			3s	4		

Exercise	Week	Tempo	Sets	Reps	RIR	Weight
Single Leg DB RDL with Support		1-3-1-1	3	6 to 8		
DB Single Leg Hip Extension Isometric			3	20s		
CKC Clam at Wall with Knee Push on Box (Add Medball)			3	30s		
Dowel Overhead Forwad Puddle Step w/ Pause		1-3-1-1	5	5		
Keiser Knee Extension (100-60 deg): Drop Set	Week 3		2s	Failure	0	
	Week 4		2s	Failure	0	

WEDNESDAY — Weeks 3-4

Note: 2 power blocks (2 each side) / Slant Board is Prefered / Work on Push off

Exercise	Week	Tempo	Sets	Reps	RIR	Weight
Narrow Stance Hexbar Squat From Power Block	Week 3		4	6 to 8	2 to 3	
DRIVE UP FAST	Week 4		4	6 to 8	2 to 3	
Reverse Step Down to March at Wall (6" box)			3s	4		

Exercise	Week	Tempo	Sets	Reps	RIR	Weight
Hexbar RDL on Power Rack			3	6 to 8		
Addcutor Plank			3	30s		
CKC Clam at Wall with Knee Push on Box (Add Medball)		1-5-1-1	3	30s		
DB Ankle Banded DB Monster Walk			3	10yds		
Shuttle Press: Slow Lower (Up on 2 / Down on Surgical)	Week 3	ALAP	3	8		
	Week 4	ALAP	3	8		

Give What You Can Today

FRIDAY — Weeks 3-4

Note: Use 6" box / Place TKE band around Sled and Surgical Knee

Exercise	Week	Tempo	Sets	Reps	RIR	Weight
Pinnocio Split Stance Squat	Week 3	1-15-1-1	3s,1ns	4	2 to 3	
	Week 4	1-20-1-1	3s,1ns	3	2	
Reverse Step Down to March at Wall (6" box)			3s	6 to 8		

Exercise	Week	Sets	Reps	RIR	Weight
Single Leg DB RDL with Support		3	6 to 8		
DB Single Leg Hip Extension Isometric		3	20s		
CKC Clam at Wall with Knee Push on Box (Add Medball)		3	30s		
Dowel Overhead Forwad Puddle Step w/ Pause		5	5		
Keiser Knee Extension (100-60 deg): Drop Set	Week 3	3	Failure	0	
	Week 4	3	Failure	0	

BIOMECHANICS OF PRIMARY ACL INJURY

Mechanisms for Noncontact Anterior Cruciate Ligament Injuries

Knee Joint Kinematics in 10 Injury Situations From Female Team Handball and Basketball

Hideyuki Koga,* MD, PhD, Atsuo Nakamae, MD, PhD, Yosuke Shima, MD, PhD,

-Low knee flexion angle observed at initial contact **(~23^{o})**
-Rapid valgus development within **40 ms after IC**
-Quadriceps anterior shear component is large at
a low flexion angle

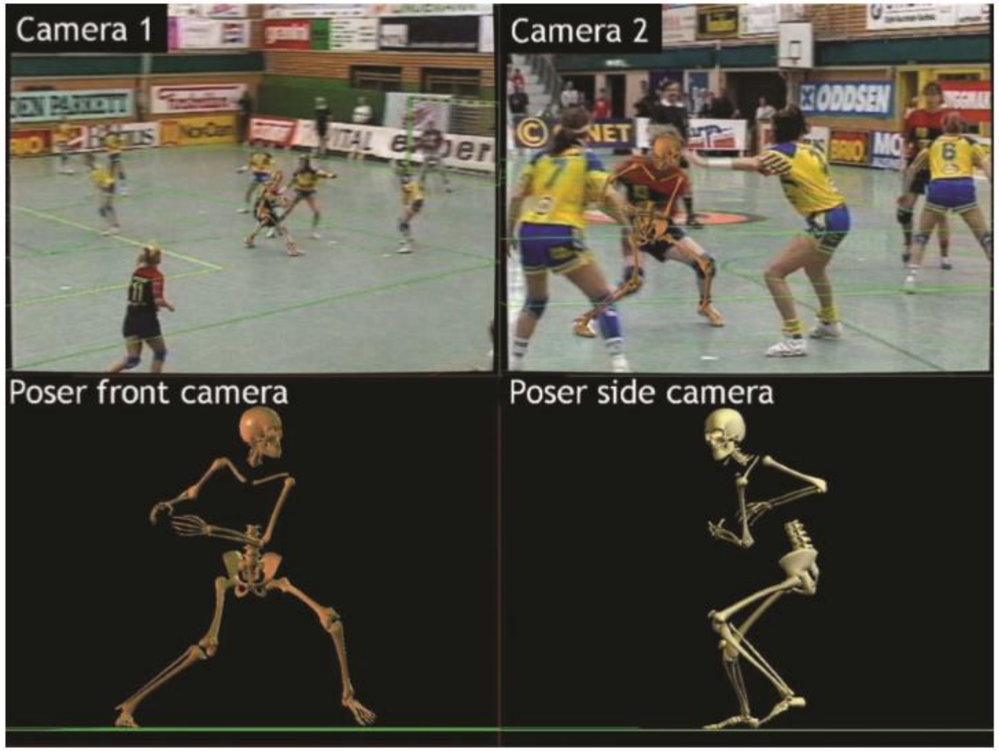
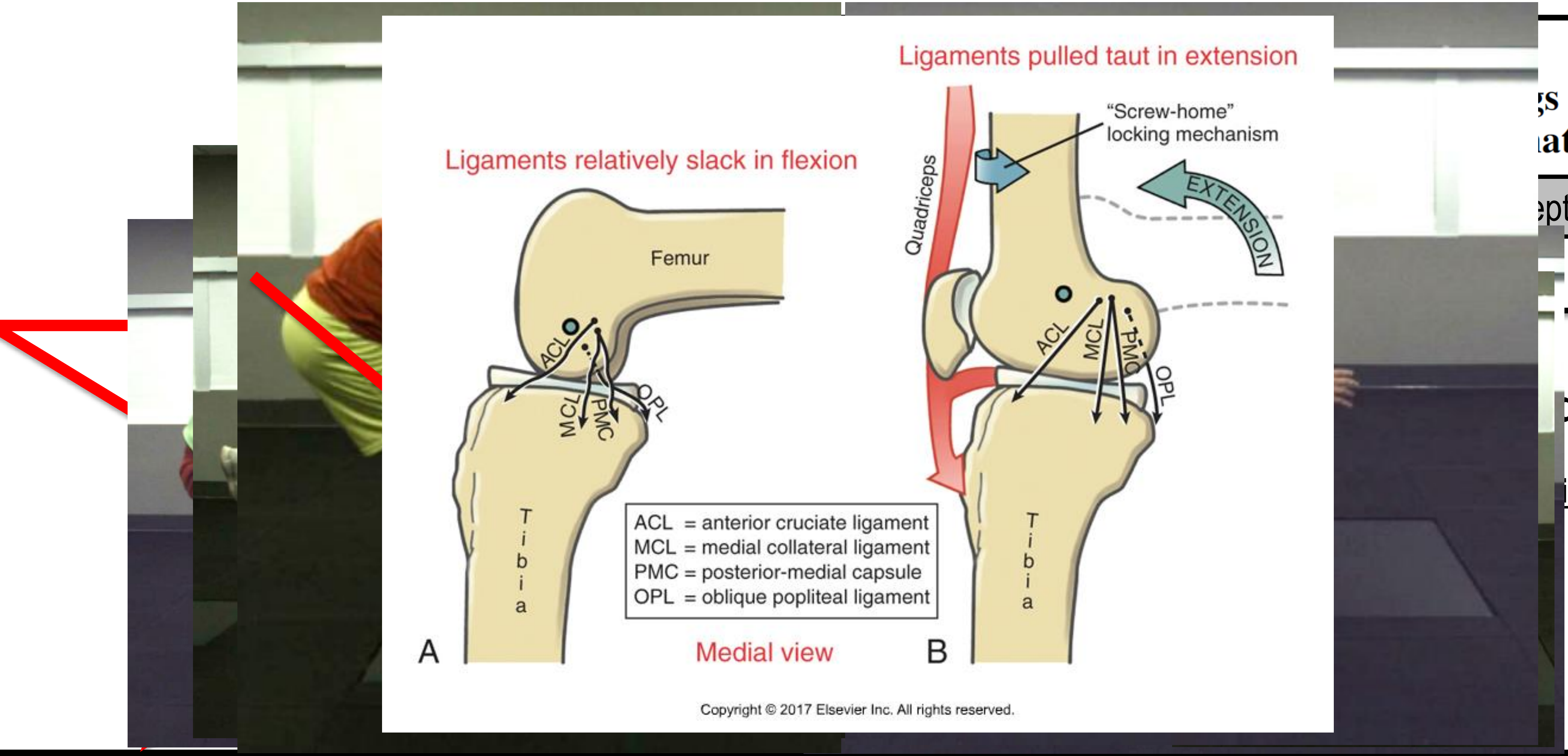


Figure 1. An example of a video matched in Poser. Case number 2, 2-camera team handball injury situation 40 milliseconds after initial contact (IC). The 2 upper panels show the customized skeleton model and the handball court model superimposed on and matched with the background video image from cameras 1 and 2. The bottom 2 panels show the skeleton model from a frontal (lower left) and side (lower right) view created in Poser.

LANDING MECHANICS IN REHABBING ACLR



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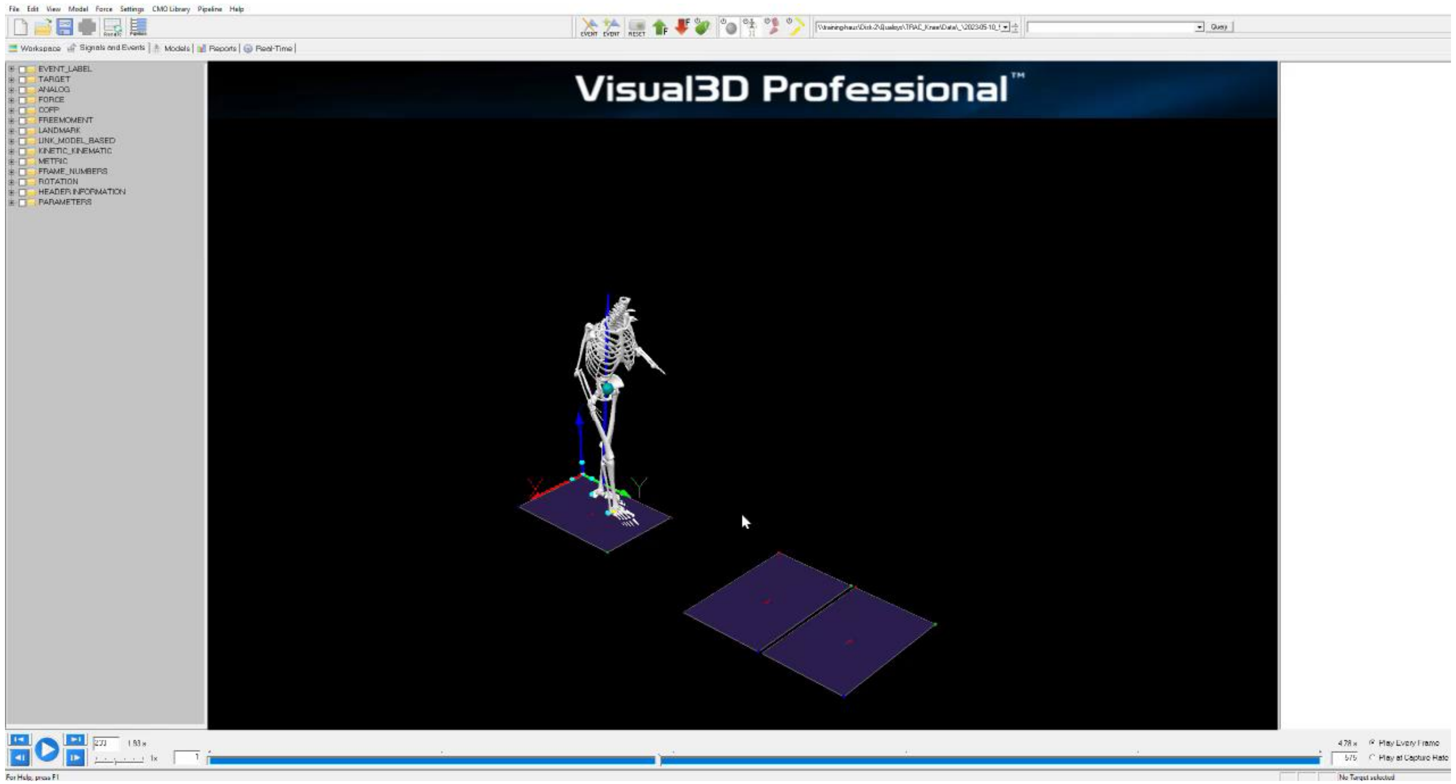
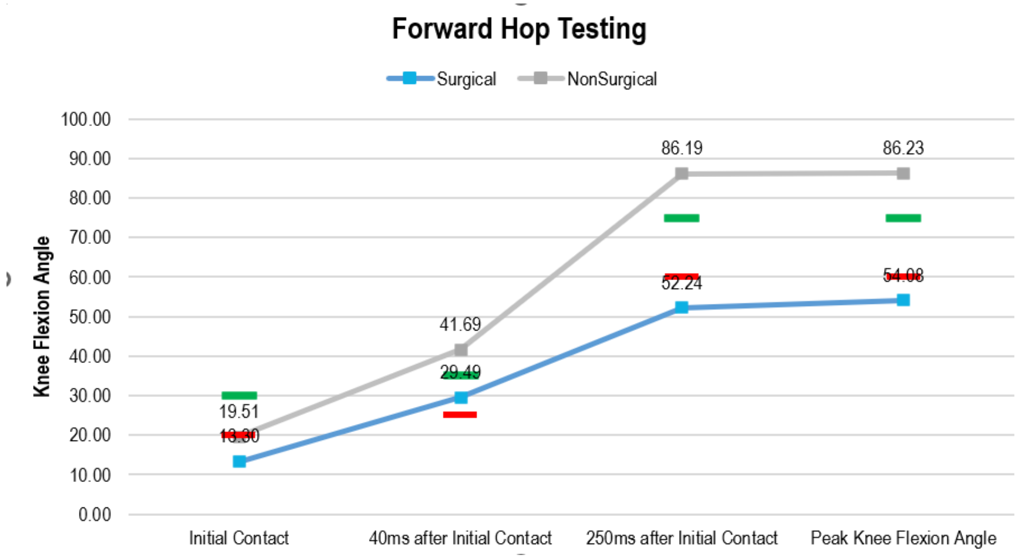
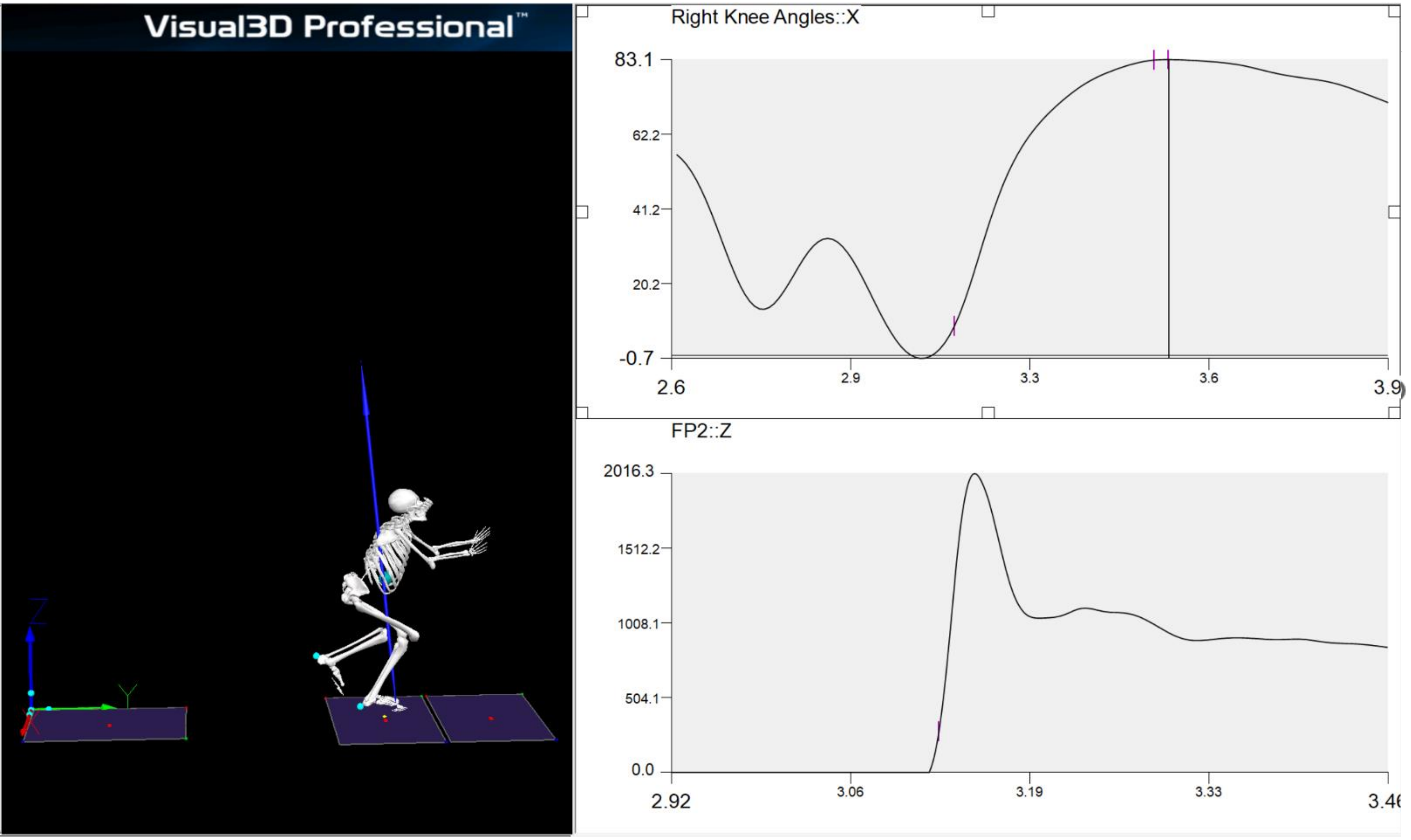
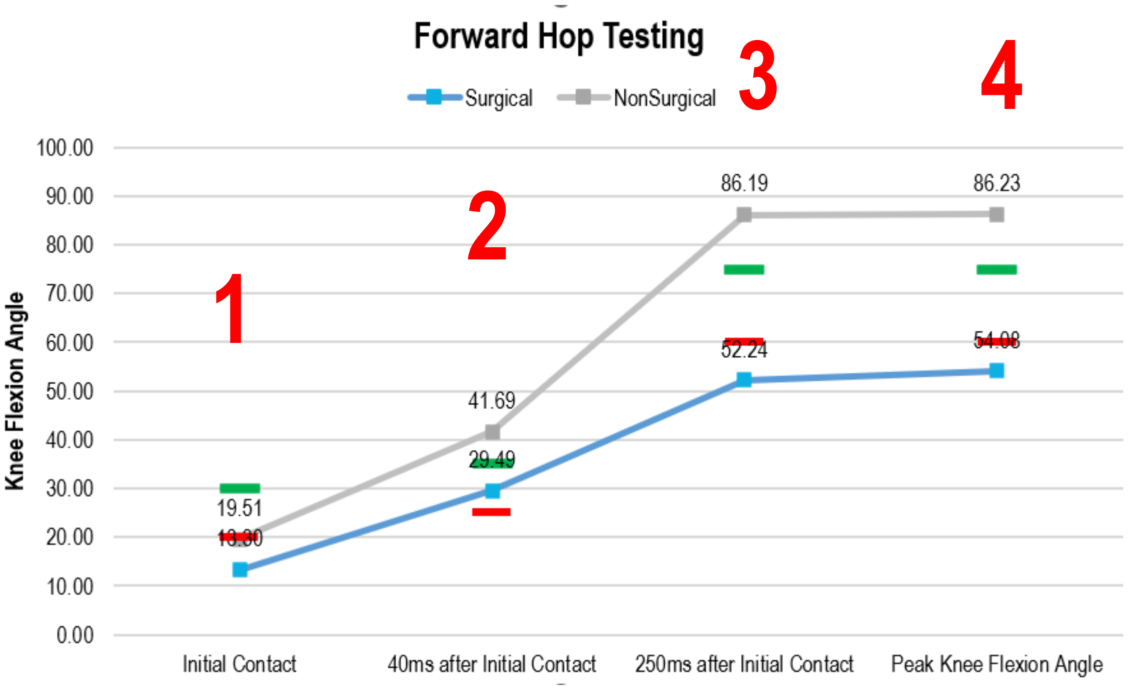
ALL TOGETHER NOW!



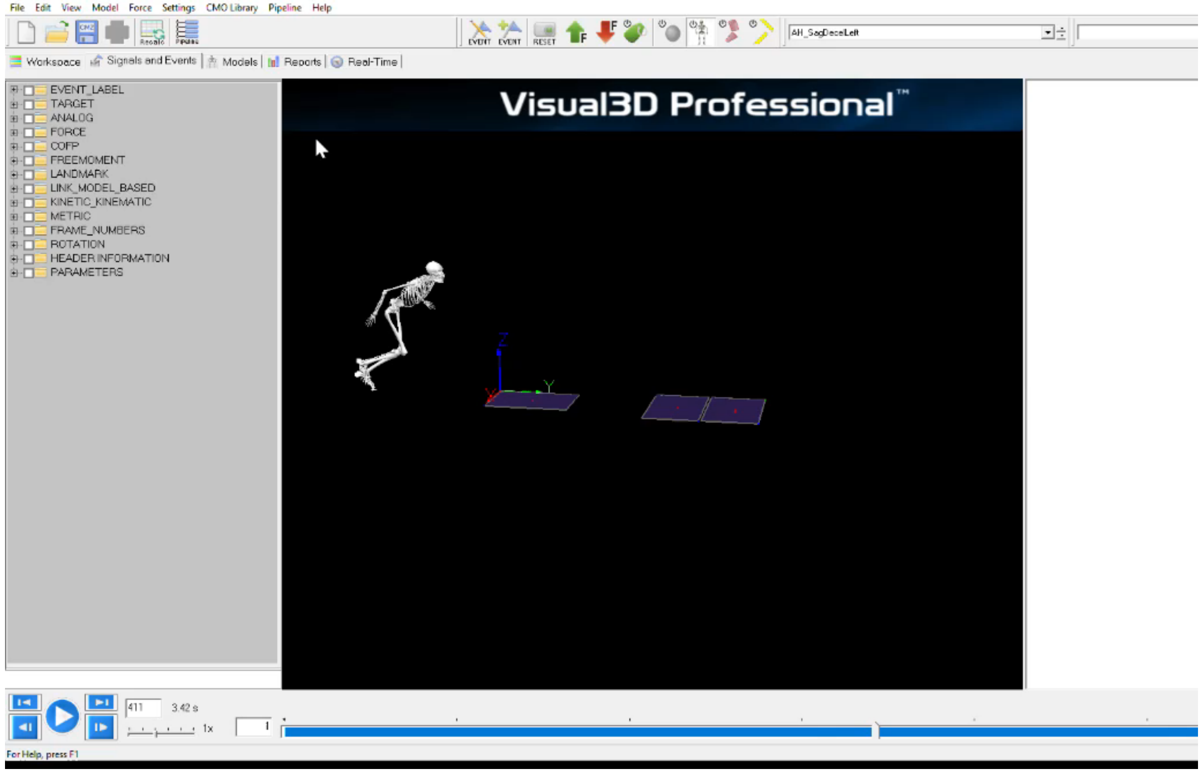


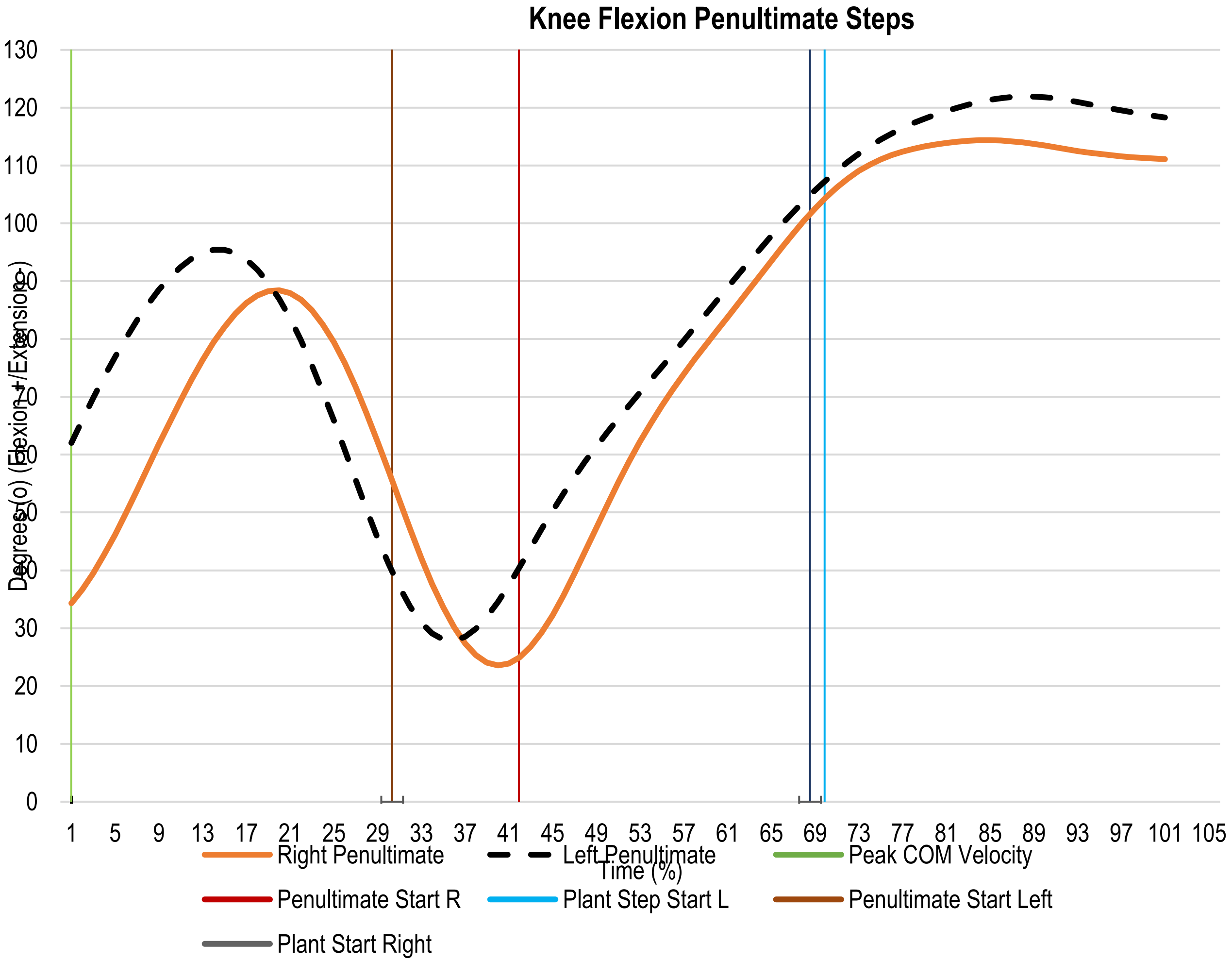
ALL TOGETHER NOW!





SAGITTAL DECELERATION



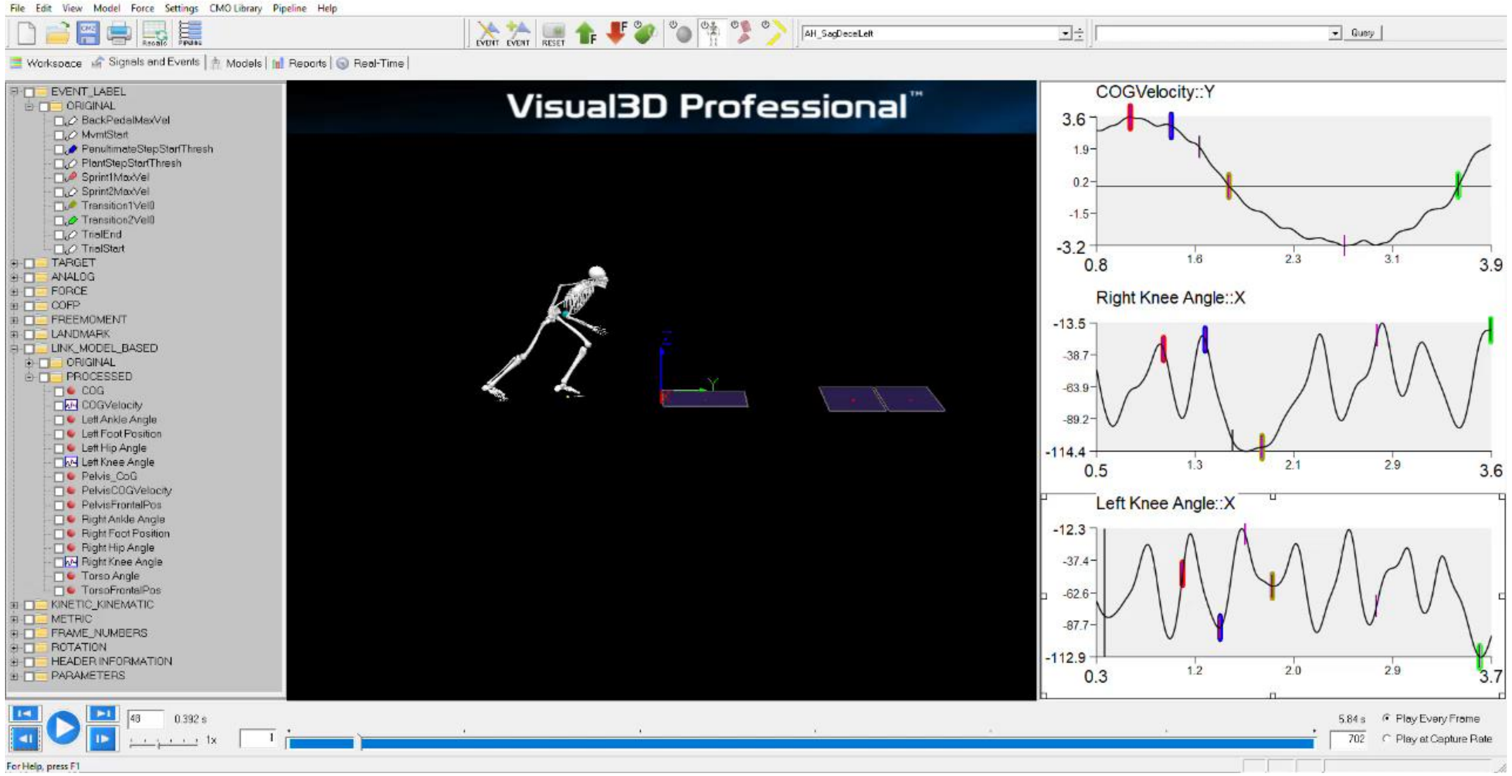


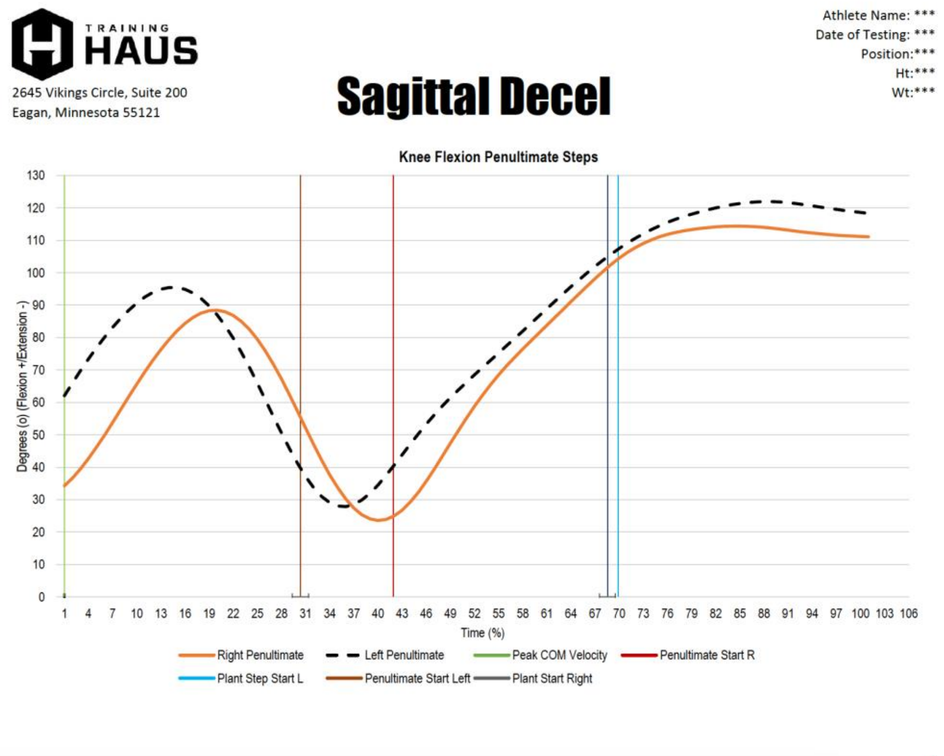
TWIN CITIES ORTHOPEDICS
TRAINING HAUS

What do we do about it?! : Sagittal Deceleration

TWIN CITIES ORTHOPEDICS
TRAINING HAUS

SPORT SPECIFIC MOTION CAPTURE-DECELERATION ANALYSIS

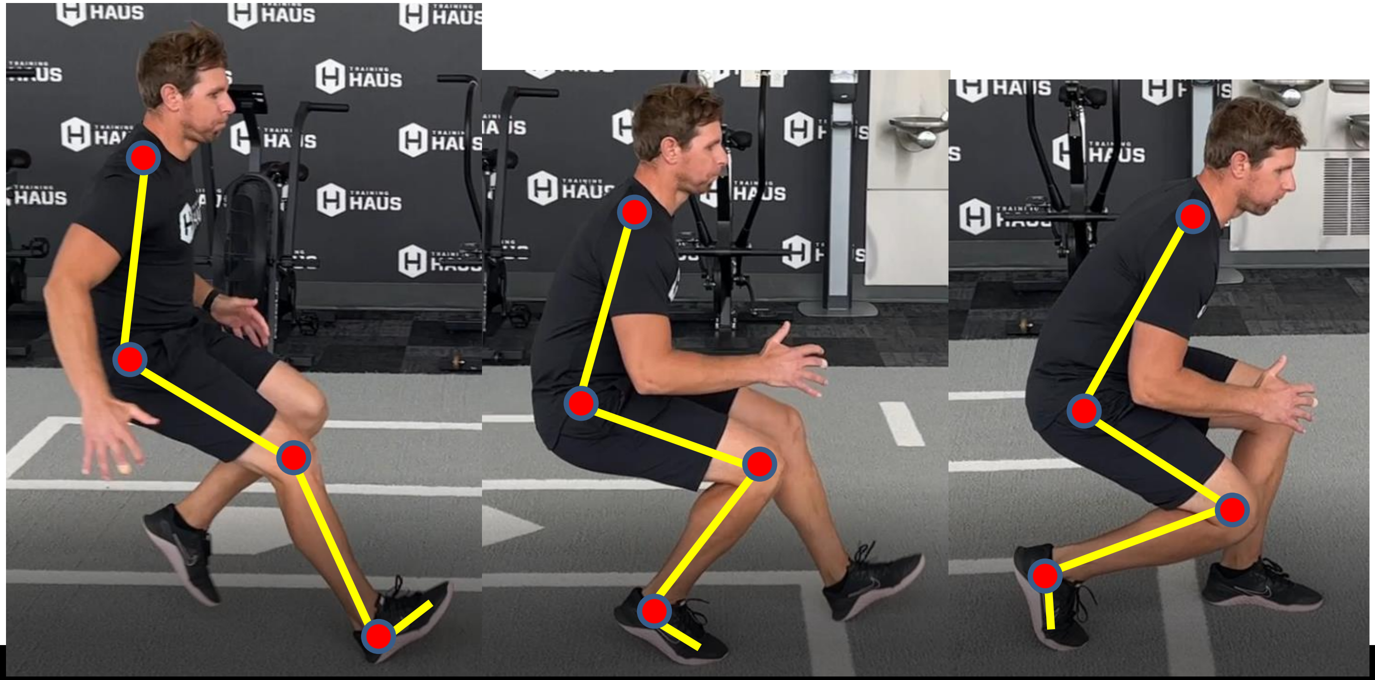




What do we do about it?! : Sagittal Deceleration

Linear Deceleration Rehab Progression Considerations for ACLR

1. Break down movement needs Kinematically
2. Build Progression Kinetically



Penultimate Step

1. Foot Contact Ahead of COM
2. Trunk/Hip/Knee Simultaneous Flexion
3. Center of Mass Down/Forward
4. Spending Time on Penultimate Step (Load)
5. Weight Shift onto Final Step (Plant)

Rehabilitation Considerations: Sagittal Deceleration

Deep(er) Knee Flexion Angles + Large External Knee Moments + High-Velocity Eccentric Contractions = HIGH LOAD

Rehabilitation Considerations: Sagittal Deceleration

Deep(er) Knee Flexion Angles + Large External Knee Moments + High-Velocity Eccentric Contractions = HIGH LOAD

How do we get here?

Sagittal Deceleration Progression

Conscious Technique Education → Unconscious Reactive Movement

1. Fundamentals
2. Known/Expected Pattern
3. Patterned Reaction
4. Open Environment Reaction

Each Level Progresses in

- Guided RPE
- Range of motion
- Volume
- Speed
- Reactivity
- Skill Level of Opponent

To address individual restrictions/level of activity

SAGITTAL DECELERATION: FUNDAMENTALS

Lunge Weight Shift

1. Positive Shin angle
2. Parallel Shin/Spine During Weight Transition
3. Encourages Hip/Trunk/Knee Association

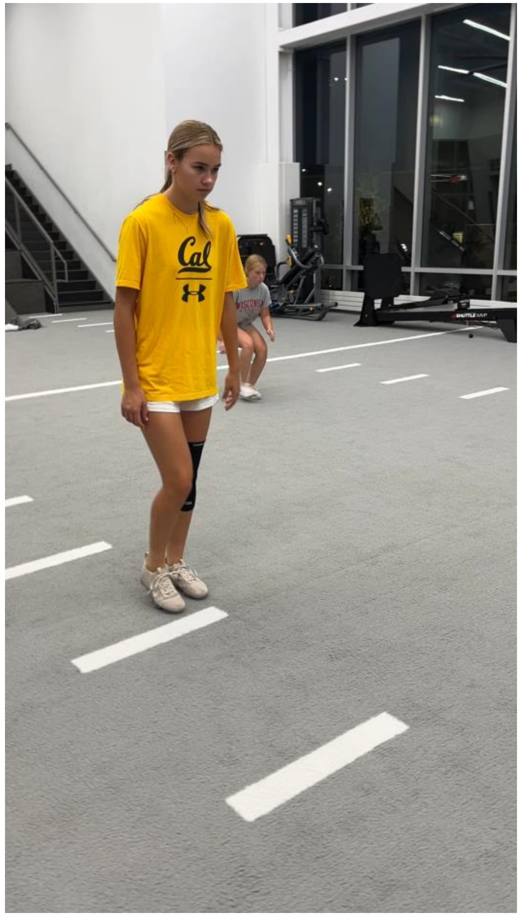
Sagittal Deceleration: Fundamentals

Step Load Plant

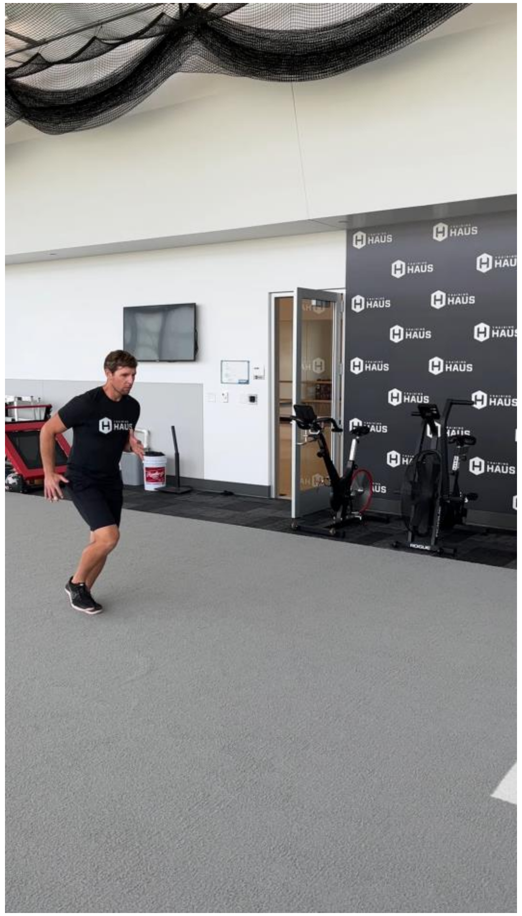
Bound to Load Plant

Ankling to Load Plant

- Initiates Ground Contact



- Increases Rate of Loading



- Focuses on Timing

Sagittal Deceleration: Fundamentals

Box Drop Load Plant

Level 1:
Increasing **Vertical Force** Demands on Load Step

Level 2:
Increasing **Horizontal Force** Demands on Load Step

SAGITTAL DECELERATION: KNOWN/EXPECTED PATTERN

5yd Decel

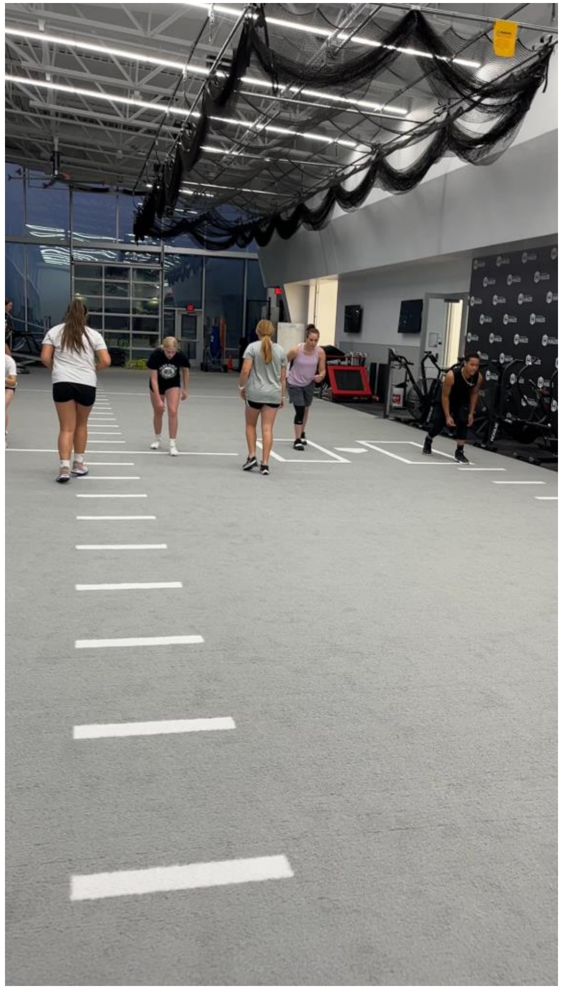
Application of Fundamental Steps to More Systemic Movement

- Increases Speed
- Externalizes Focus

10yd Decel + Jump

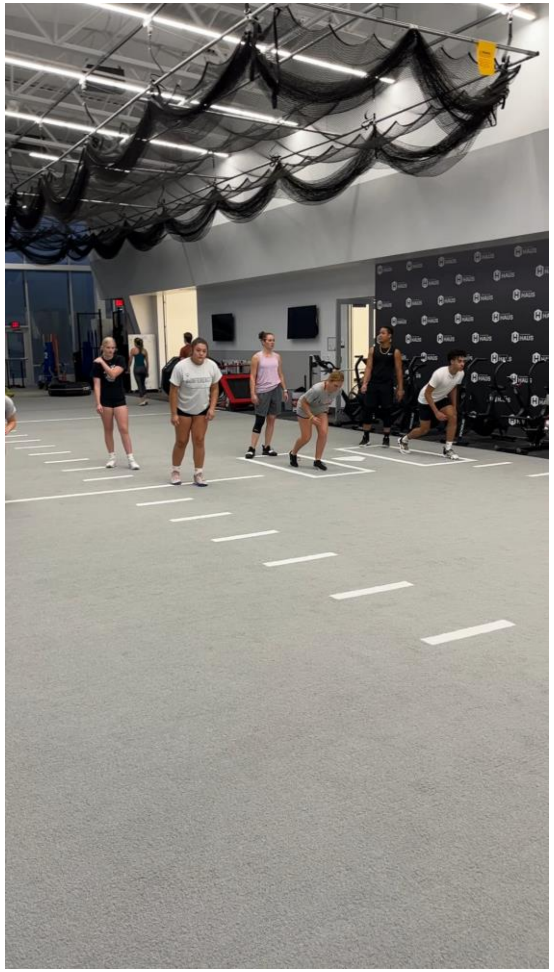
- Increase in Step Volume
- Increase in Speed
- Jump forces a Full Deceleration

*Note slight anterior displacement during landing

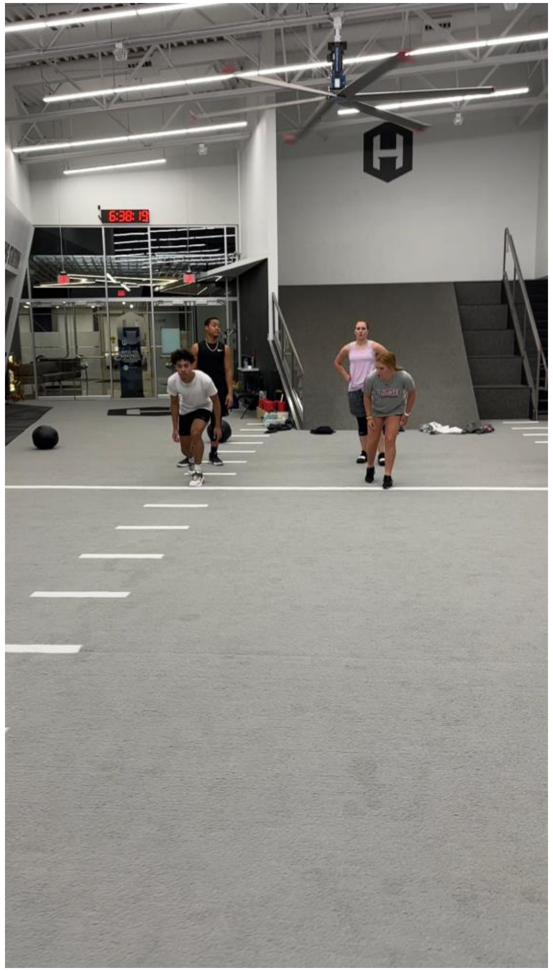


SAGITTAL DECELERATION: PATTERNED REACTION

Decel On Auditory Cue



- Pattern Is Known
- Externalizes Focus away from Movement Mechanics
- Promotes Unconscious Movement Habits
- Good assessment of what is being learned



Decel On Visual Cue

SAGITTAL DECELERATION: OPEN ENVIRONMENT REACTION

Make a Move/Play Some Defense

- Pattern Is **UnKnown**
- React to the Environment Presented
- Do they apply fundamentals without thinking of them?

Progression Levels:

1. Speed
2. Start Position
3. Offense/Defense
4. Skill of Opponent
5. Size of Environment
6. Sport Specific Scenarios

Programming Deceleration/Movement Training

Conscious Technique Education → Unconscious Reactive Movement

1. Fundamentals
   - 2-3 sets 6-10reps/10-20yds
2. Known/Expected Pattern
   - 2-3 sets 4-5 reps each
3. Patterned Reaction
   - 2-6 sets 4-5 reps each
4. Open Environment Reaction
   - 2-10 reps with increasing duration and complexity

Each Level Progresses in

- Guided RPE
- Range of motion
- Volume
- Speed
- Reactivity
- Skill Level of Opponent

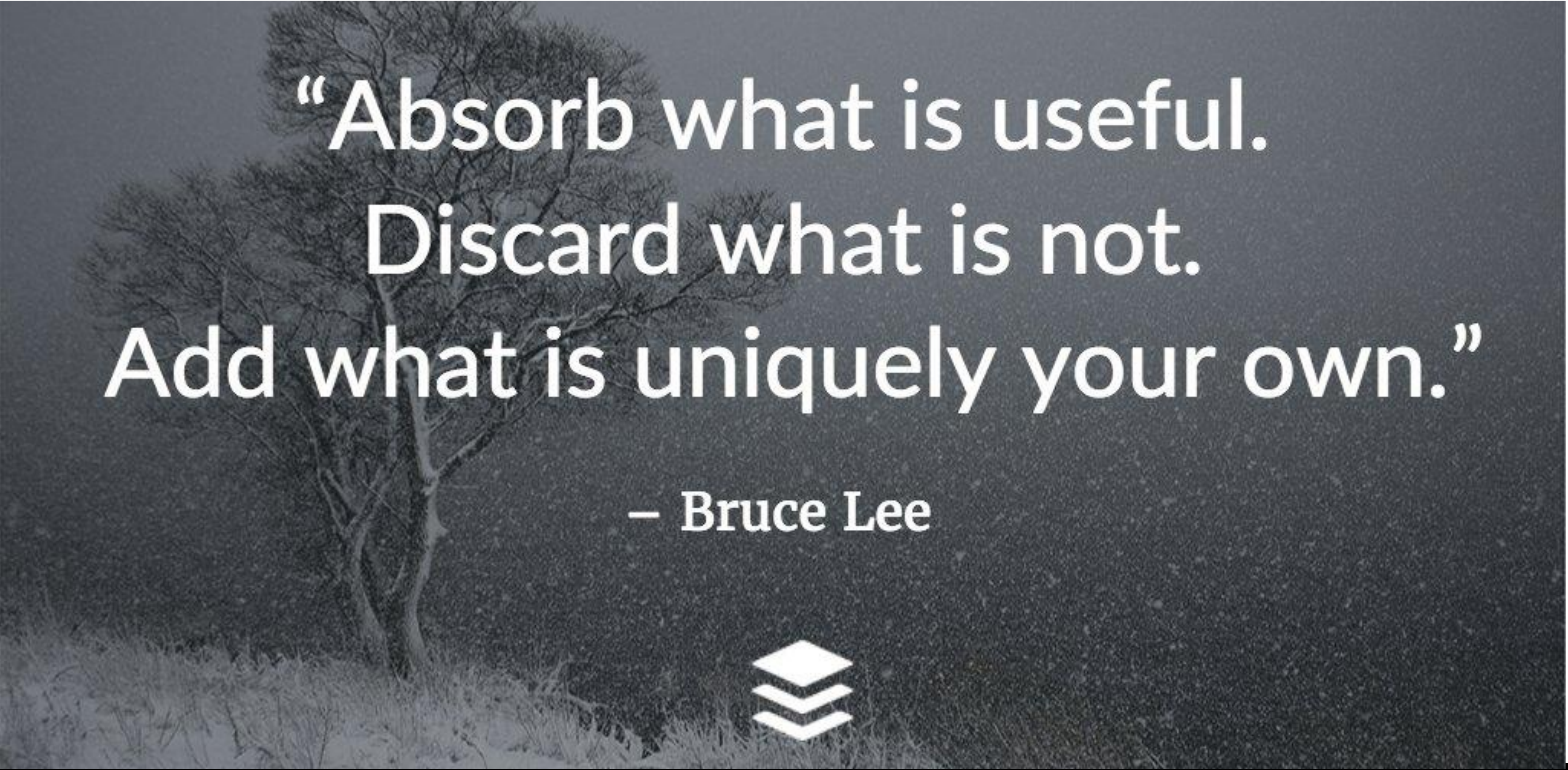
To address individual restrictions/level of activity

USING THE CONSTRAINTS LED APPROACH IN RETURN TO PLAY

STUART BORNE, M.ED., ATC, CSCS

CONFLICTS

- No conflicts of interest
- Views expressed are mine
- Views may not be the same as my employer or colleagues
- Please use discretion when using the information contained in this presentation



TWIN CITIES ORTHOPEDICS
TRAINING HAUS

QUESTIONS TO CONSIDER

- What is functional or sport specific movement?
- What makes a movement correct?
- What makes a movement incorrect?
- When should you give feedback for a movement?
- When should you not?
- How do you change the way someone moves?
- How can you tell if it works?

WHICH DEADLIFT IS CORRECT?


STRENGTH FOUNDATIONS
Developing the 7 basic movements in the weight room create a foundation for athletic strength and advanced training later
Triple Extension
Push
Pull
Hinge
Single Stance
Brace
Rotation

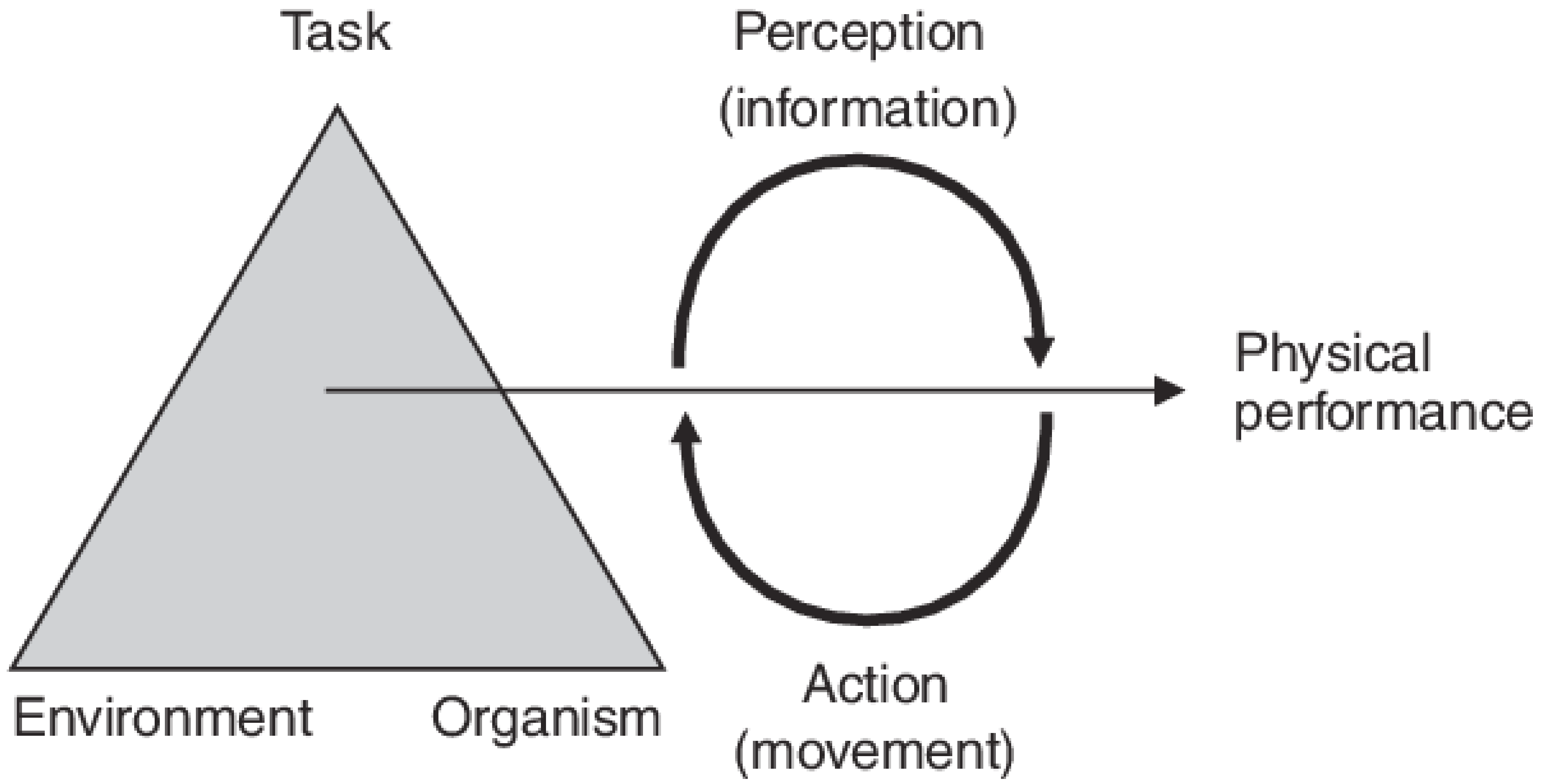

STRENGTH FOUNDATIONS
Developing the 7 basic movement patterns in the weight room creates a foundation for athletic strength and advanced training later
Triple Extension
Push
Pull
Hinge
Single Stance
Brace
Rotation



CONTEXT MATTERS

- https://twitter.com/VernonGriffith4/status/814887079343747072

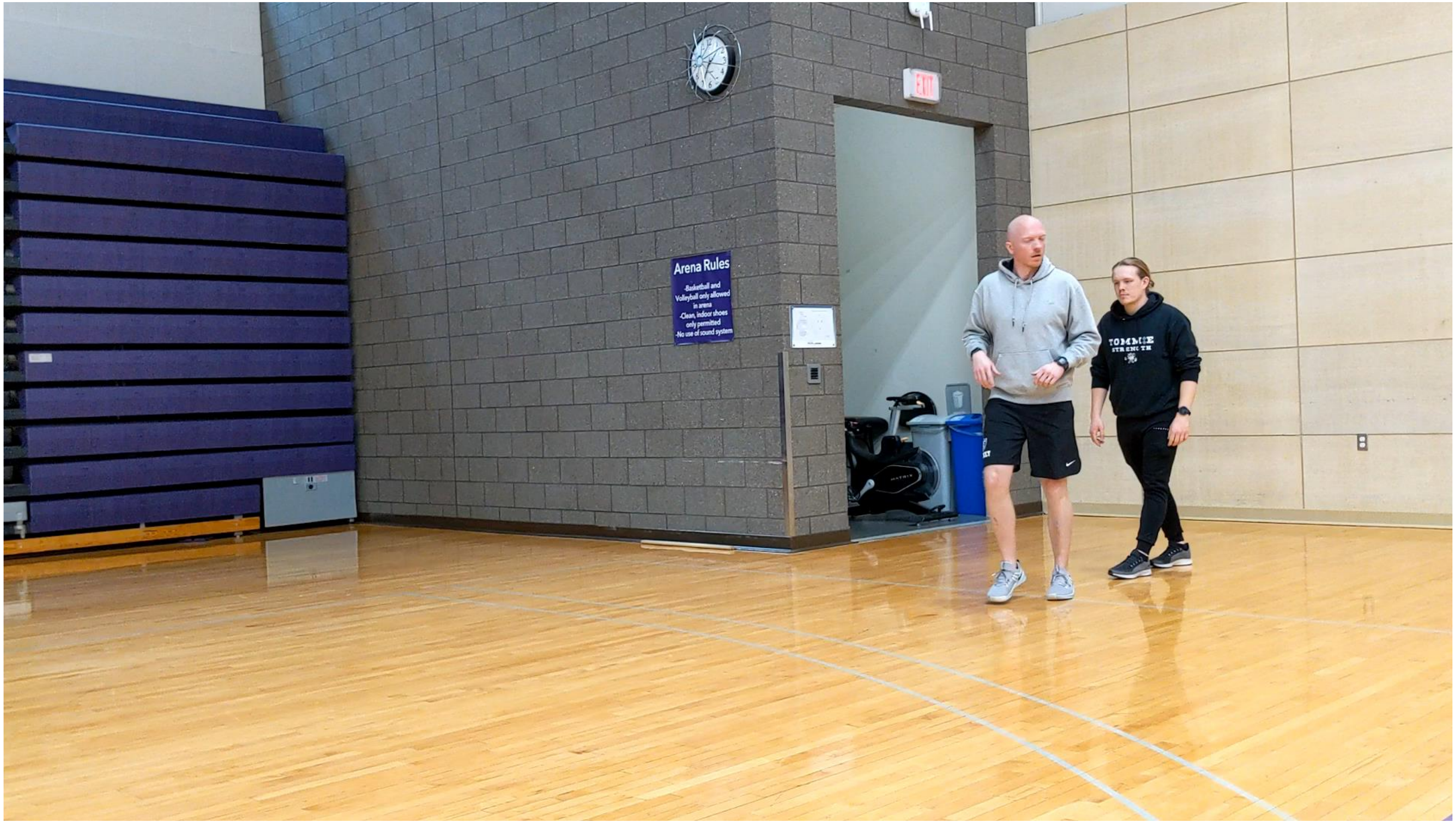
CLA & PERCEPTION/ACTION



SPORTS CONSTRAINTS EXAMPLES

- Athlete – speed, strength, power, flexibility, weight, body comp, injury history, emtions, understanding of the game, exercise, or drill, shoe wear
- Task – rules/instructions, time, speed, implements, equipment, exercises, drills
- Environment – space, surface, other people, weather, light, sound, view or vision, obstacles


EXIT
Arena Rules
-Basketball and Volleyball only allowed in arena
-Clean, indoor shoes only permitted
-No use of sound system
TOMMIE STRENGTH


EXIT
Arena Rules
-Basketball and Volleyball only allowed in arena
-Clean, indoor shoes only permitted
-No use of sound system
TOMMIE STRENGTH


GO TOMMIES!

CHANGE THE TASK

DON'T DROP THE FOAM ROLLER

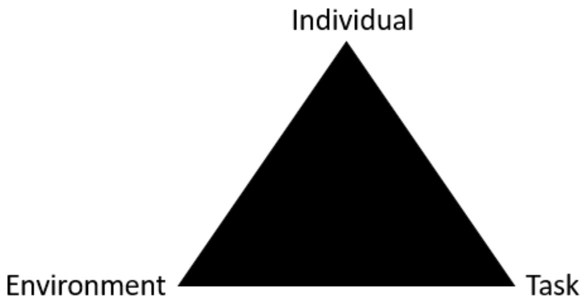
CHANGE THE INSTRUCTIONS

KEEP THE TENNIS BALL IN THE AIR

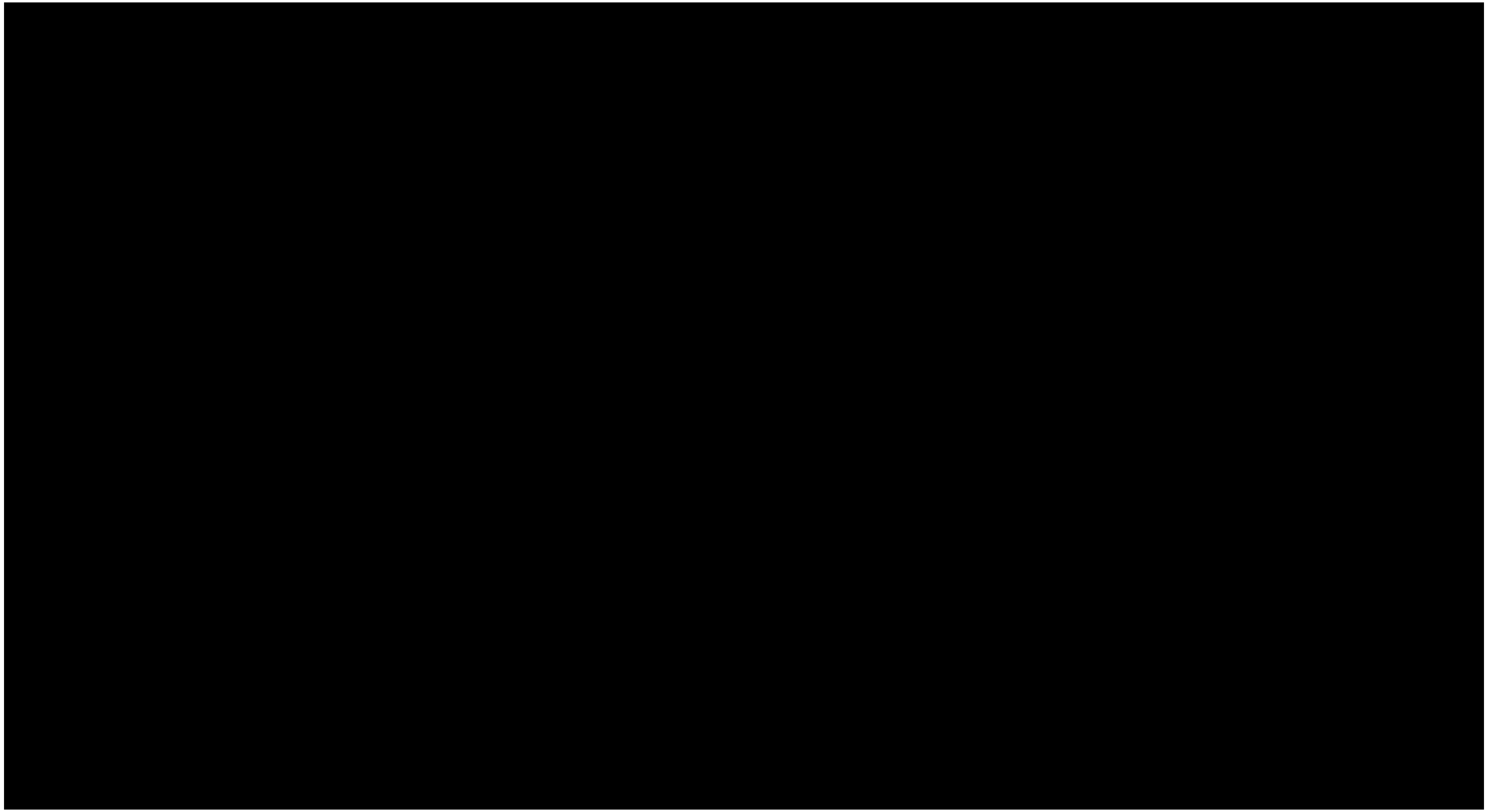
CHANGE THE IMPLEMENT

GIVE THEM TIME TO FIGURE IT OUT

CONSTRAINTS LED APPROACH

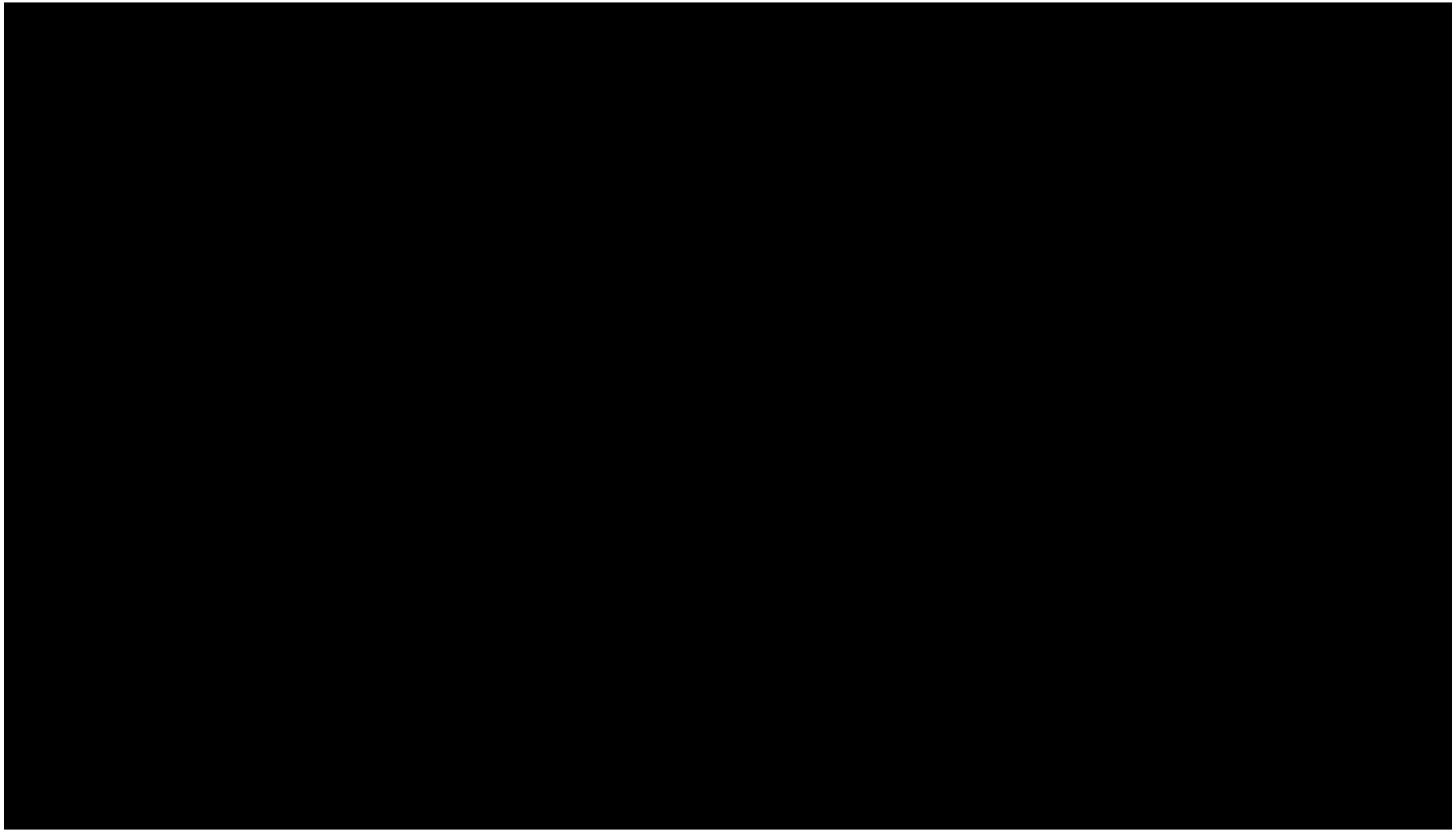


HEADERS



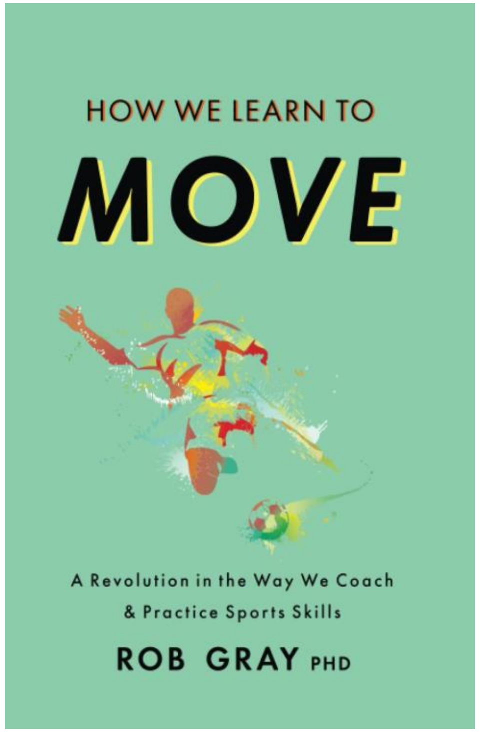
CHANGE THE TASK

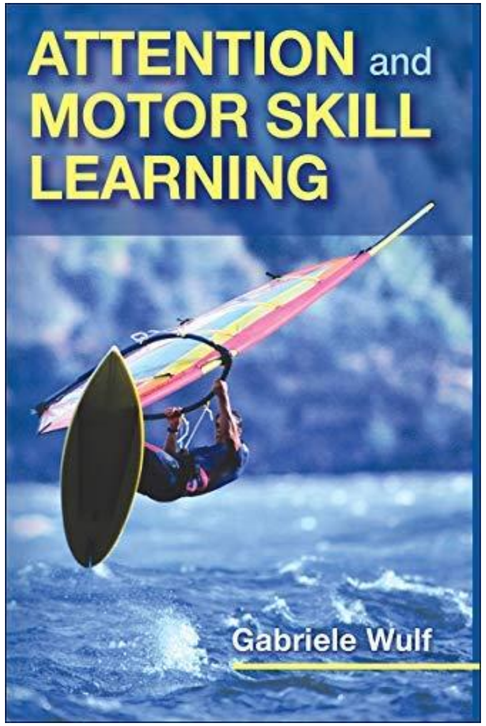
CHANGE THE ENVIRONMENT



RESOURCES

- Dustin Grooms – research, presentations, podcasts
    - Principles of Motor Learning to Support Neuroplasticity After ACL Injury: Implications for Optimizing Performance and Reducing Risk of Second ACL Injury





DISCUSSION

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