COLLEGE OF HEALTH AND HUMAN SERVICES
THE UNIVERSITY OF TOLEDO

Treating Persistent Muscle Inhibition: What To Do When You've Thrown the Kitchen Sink At It

School of Exercise and Rehabilitation Sciences
College of Health and Human Services
University of Toledo

2018 Great Lakes Athletic Trainers' Association Annual Meeting

Presenter Conflict

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No Conflict

- The views expressed in these slides and today's discussion are ours.
- Our views may not be the same as the views of our company's clients or our colleagues.
- Participants must use discretion when using the information contained in this presentation.

Learning Objectives

- Clinical impairments
- Outcomes with traditional rehabilitation
- Mechanisms of persistent muscle weakness
- Clinical strategies to overcome muscle inhibition

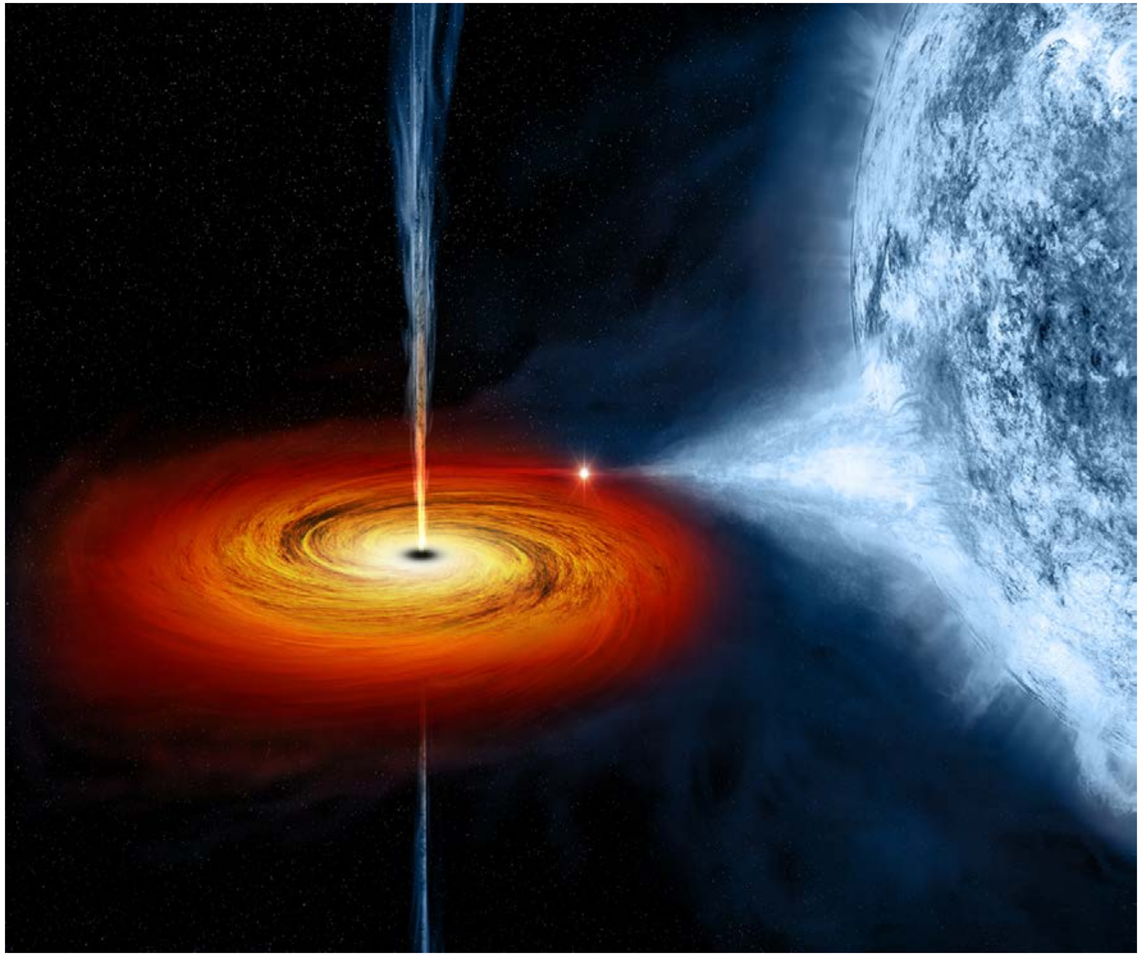
Patellofemoral Pain (PFP)

- **Diffuse insidious pain**
  - Anterior or retro patella
  - Medial and lateral border of patella
  - Exacerbated with activity
    - Jumping
    - Running
    - Prolonged sitting
    - Squatting
    - Stair ambulation
- **Diagnosis by exclusion**

Boudreau 2016

Incidence and Prevalence

- **Incidence** (Smith 2018)
  - General population: 22.7%
  - Adolescents: 28.9%
  - Military: 13.5%
- **Prevalence** (Smith 2018)
  - Adolescents: 7.2%
  - Female adolescents: 22.7%
- **2.2 times greater in females** (Boling 2010)



Impact of PFP

- **Activity Modification**
  - ~70% modify or stop activity level or sports participation (Rathleff 2016)
  - Individuals with PFP take 3,400 less steps per day compared to healthy individuals (Glaviano 2017)
- **Decreased quality of life** (Cheung 2013)
- **Increased anxiety, depression, catastrophizing, and fear of movement** (Maclachlan 2017)
  - Relate to pain and reduced physical function

PFP Impairments

Strength
- Quads
- GMed

Soft Tissue
- Quads
- Hamstrings

Patella Maltracking
- Abnormal PFJ

Foot/Ankle
- Forefoot valgus
- Rearfoot eversion
- Mid-foot width

Quality of Movement
- Hip Adduction
- Hip IR
- Trunk Flexion

Neuromuscular Activity
- VMO:VL
- GMed
- Hip Adductors

Relationship Between Impairments

- **Quadriceps strength and subjective function**
  - AKPS (Nakagawa 2013)
    - Strong knee extensors and hip abduction
  - ADLS (Glaviano 2017)
    - Moderate knee extensors and hip ER
  - W-VAS (Nakagawa 2013)
    - Negative moderate relationship with knee extensors and hip ER

Relationship Between Impairments

- **Quadriceps function and kinematics**
  - Decreased knee flexion during jumping tasks (Kim 2017)
  - Altered lower extremity energy absorption (Read 2017)
- **Quadriceps function and kinetics**
  - Decreased plantarflexion and knee extension moments (Kim 2017)

Learning Objectives

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- Clinical strategies to overcome muscle inhibition

Treatment Options

Posterolateral Hip Muscle Strengthening Versus Quadriceps Strengthening for Patellofemoral Pain: A Comparative Control Trial

Khalil Khayambashi, PT, PhD,[a] Alireza Fallah, PT, MS,[a] Ahmadreza Movahedi, PhD,[a] Jennifer Bagwell, DPT,[b] Christopher Powers, PT, PhD[b]

Clinical Rehabilitation 2006; 20: 1050–1057

Biofeedback supplementation to physiotherapy exercise programme for rehabilitation of patellofemoral pain syndrome: a randomized controlled pilot study

Selina LM Yip Department of Rehabilitation Sciences, The Hong Kong Polytechnic University and Department of Physiotherapy, Yan Chai Hospital and Gabriel YF Ng Department of Rehabilitation Sciences, The Hong Kong Polytec University, Hong Kong, China

LAURA KOOIKER, PT, MSc[1] • INGRID G.L. VAN DE PORT, PhD[1,2] • ADAM WEIR, MBBS, PhD[3] • MAARTEN H. MOEN, MD, PhD[2,4]

Effects of Physical Therapist–Guided Quadriceps-Strengthening Exercises for the Treatment of Patellofemoral Pain Syndrome: A Systematic Review

Strengthening of the Hip and Core Versus Knee Muscles for the Treatment of Patellofemoral Pain: A Multicenter Randomized Controlled Trial

Reed Ferber, PhD, ATC, CAT(C)*; Lori Bolgla, PhD, PT, ATC†; Jennifer E. Earl-Boehm, PhD, ATC‡; Carolyn Emery, PhD, BScPT*; Karrie Hamstra-Wright, PhD, ATC§

ORIGINAL ARTICLE

Outcomes of a Weight-Bearing Rehabilitation Program for Patients Diagnosed With Patellofemoral Pain Syndrome

Michelle C. Boling, MS, ATC, Lori A. Bolgla, PT, PhD, ATC, Carl G. Mattacola, PhD, ATC, Tim L. Uhl, PT, PhD, ATC, Robert G. Hosey, MD

Effect of Eccentric Isotonic Quadriceps Muscle Exercises on Patellofemoral Pain Syndrome: An Exploratory Pilot Study

Charu Eapen*, PhD; Chetan D. Nayak, MPT; Chundanveetil Pazhyaottyil Zulfeequer, MPT

RESEARCH ARTICLE

The Effect of Taping, Quadriceps Strengthening and Stretching Prescribed Separately or Combined on Patellofemoral Pain†

Marjon Mason[1]*, Susan L. Keays[2] & Peter A. Newcombe[3]

RODRIGO DE MARCHE BALDON, PT, MS[1] • FÁBIO VIADANNA SERRÃO, PT, PhD[1]
RODRIGO SCATTONE SILVA, PT, MS[1] • SARA REGINA PIVA, PT, PhD[2]

Effects of Functional Stabilization Training on Pain, Function, and Lower Extremity Biomechanics in Women With Patellofemoral Pain: A Randomized Clinical Trial

Original research

Effects of femoral rotational taping on pain, lower extremity kinematics, and muscle activation in female patients with patellofemoral pain

Chen-Yi Song[a], Han-Yi Huang[a], Sheng-Chang Chen[b], Jiu-Jenq Lin[a,*], Alison H. Chang[c]

The Effects of Quadriceps Strengthening on Pain, Function, and Patellofemoral Joint Contact Area in Persons with Patellofemoral Pain

Short-Term Treatment Outcomes

- **Short-term improvement in strength, pain, and subjective function** (Baldon 2014, Crossley 2002, Dolak 2011, Kooiker 2014)
- **Responders vs. non-responders of rehabilitation** (Bolgla 2016)
  - Successful outcomes:
    - VAS > 2 cm
    - AKPS > 8

Table 5. *Mean ± (standard deviation) for isometric force measures (% body mass) for responders and non-responders, regardless of intervention assignment.*

	Baseline		6-week		% Change		Cohen's *d*	
	Male	Female	Male	Female	Male	Female	Male	Female
Responders	N = 36	N = 88						
Non-Responders	N = 25	N = 36						
Hip Abductors								
Responders[a]	38.8 (13.0)	32.2 (10.6)	41.0 (13.6)	34.6 (10.7)	5.7%	7.4%	0.16	0.23
Non-Responders[b]	39.2 (10.4)	33.8 (11.7)	40.4 (9.9)	34.0 (11.6)	3.1%	0.6%	0.12	0.02
Hip Extensors								
Responders[c]	27.4 (10.6)	22.1 (9.8)	31.4 (11.5)	25.0 (11.4)	14.6%	13.1%	0.36	0.27
Non-Responders[b]	31.8 (10.9)	23.6 (11.7)	31.3 (11.1)	25.2 (12.4)	-1.6%	6.8%	-0.05	0.13
Hip External Rotators								
Responders	13.0 (5.7)	12.0 (4.1)	15.0 (4.9)	12.6 (3.9)	15.4%	5.0%	0.38	0.15
Non-Responders[b]	14.1 (3.4)	11.6 (4.0)	14.7 (3.1)	12.0 (4.5)	6.0%	3.4%	0.18	0.09
Knee Extensors								
Responders[c]	44.9 (16.0)	37.4 (13.9)	50.0 (14.9)	41.3 (14.3)	11.4%	10.4%	0.33	0.28
Non-Responders[b]	47.5 (14.7)	39.7 (18.5)	47.8 (15.1)	40.5 (17.4)	0.6%	2.0%	0.02	0.04

Retaining Positive Short-Term Outcomes?

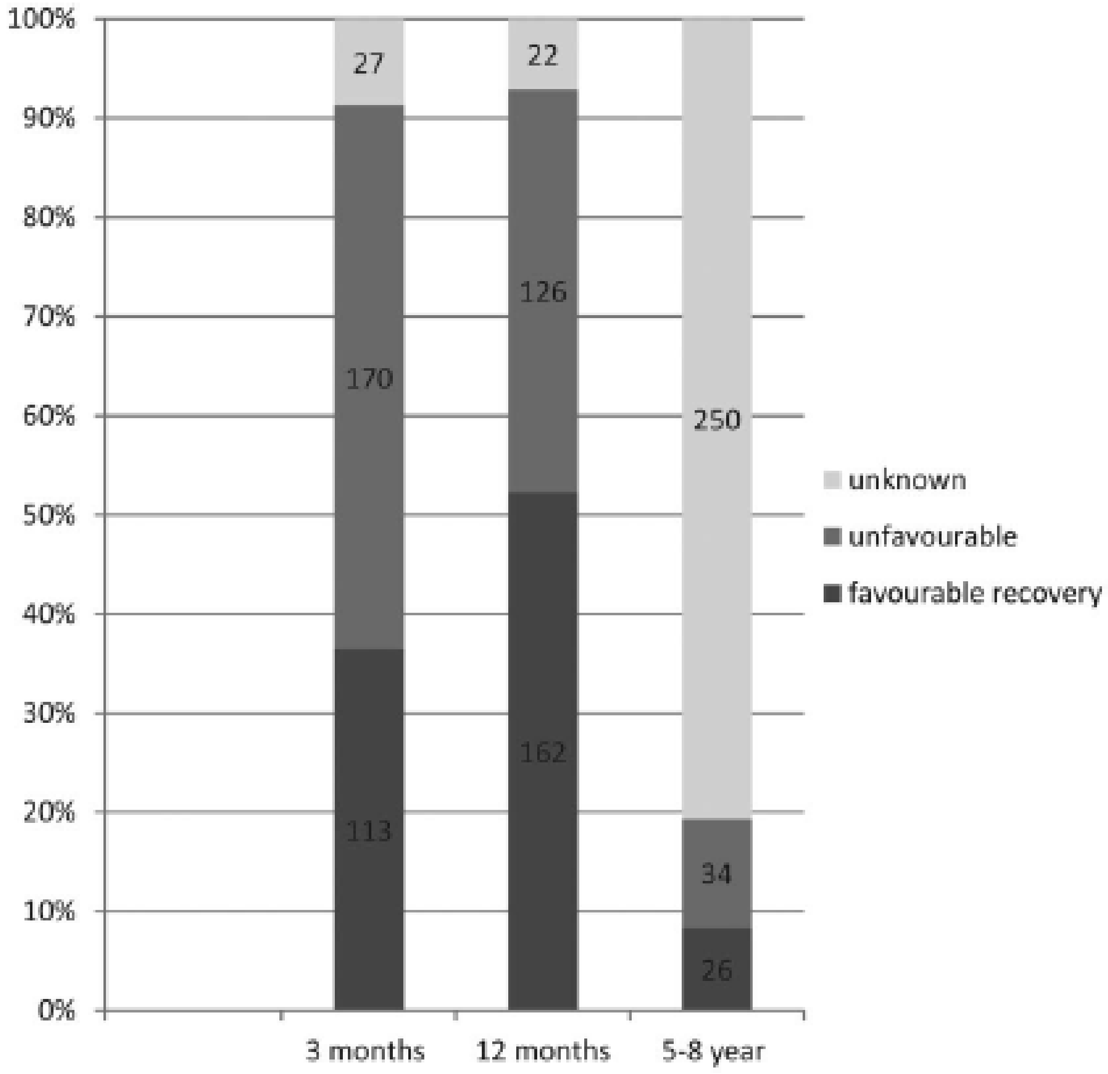
Table 4 Strength Values and 95% Confidence Intervals at Prerehabilitation, Postrehabilitation, and 6 Months Postrehabilitation, Mean (SD)

Variable	Pre, Nm/kg	Post, Nm/kg	6 mo post, Nm/kg	% change pre–post	% change post–6 mo post
HER	1.16 (0.44)	1.32 (0.45)*	1.22 (0.40)†	13.79	–7.58
	1.04–1.23	1.20–1.42	1.12–1.33		
KEXT	3.93 (1.48)	4.46 (1.54)*	3.98 (1.42)†	13.49	–10.76
	3.56–4.31	4.07–4.85	3.62–4.34		
HEXT	2.49 (1.11)	2.82 (1.21)*	2.57 (1.06)†	13.25	–8.87
	2.20–2.77	2.50–3.12	2.30–2.84		
HIR	1.42 (0.59)	1.56 (0.60)*	1.52 (0.55)	9.86	–2.56
	1.26–1.56	1.40–1.70	1.38–1.66		
HABD	3.53 (1.25)	3.69 (1.24)	3.66 (1.12)	4.53	–0.81
	3.20–3.83	3.36–3.99	3.37–3.94		

Hamstra-Wright 2017

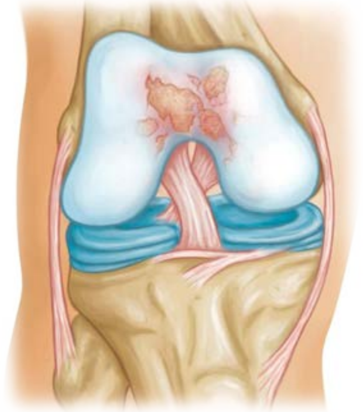
Long-Term Treatment Outcomes

- **96% have dysfunction / pain for 4+ years** (Price 1998)
- **91% had pain 16 years after diagnosis** (Stathopulu 2003)
- **Patients are not satisfied with knee function after rehab** (Lankhorst 2016)
  - 60% at 3-months
  - 44% at 12-months
  - 57% at 5-8 years



Is PFP a Precursor to OA?

- **1 in 3 patients with PFP show radiological signs of OA in the PF joint** (Kobayashi 2016)
- **1 in 4 patients who undergo TKA for PF joint OA report a history of chronic anterior knee pain** (Utting 2005)
- **Lack of prospective data, but similarities exist between PFP and PF joint OA** (Crossley 2014, Wyndow 2016)
  - Poor patellar alignment
  - Quadriceps/hip abductor dysfunction/atrophy
  - Difficulty negotiating stairs
  - Similar location of pain

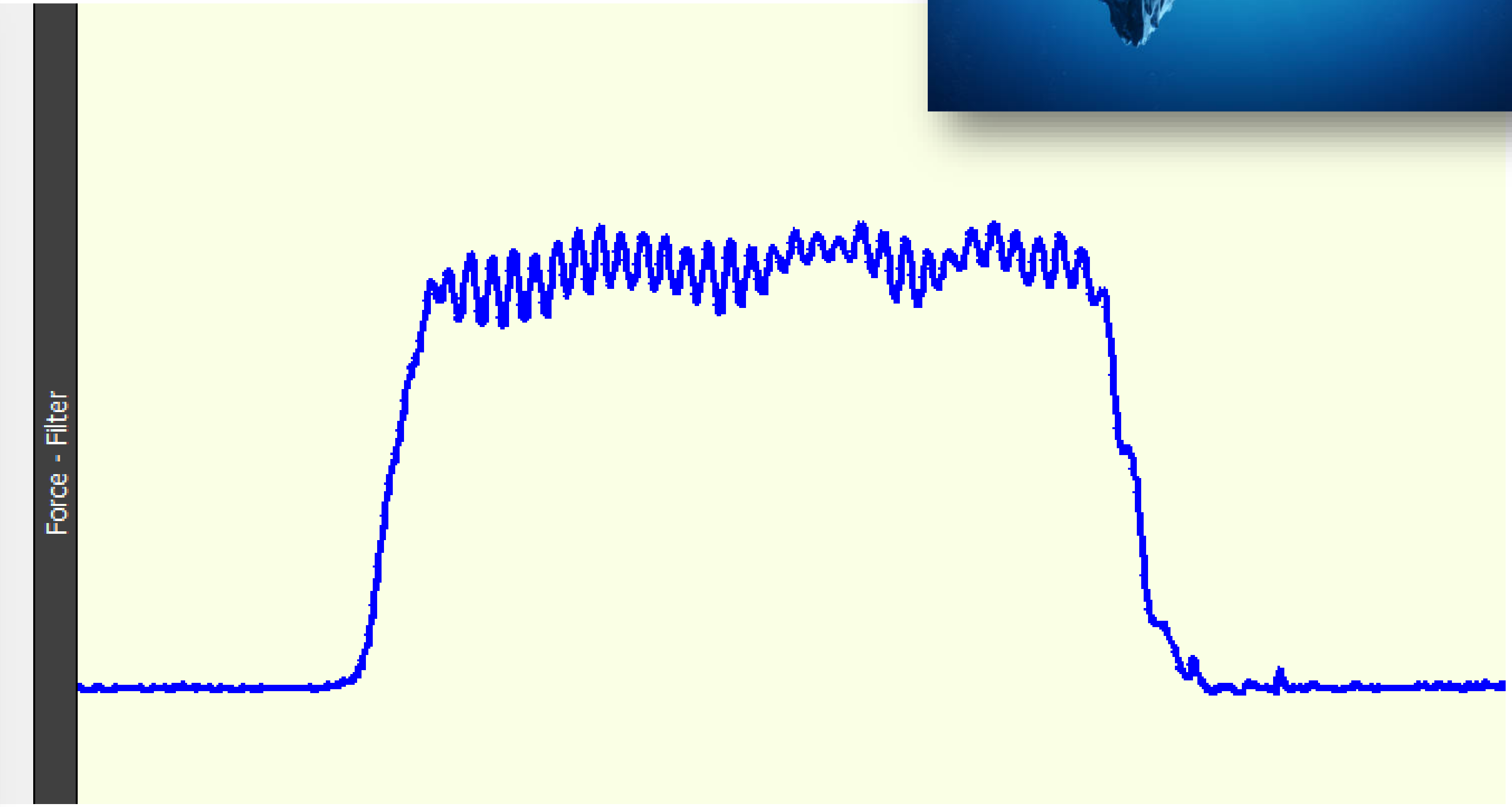


Learning Objectives

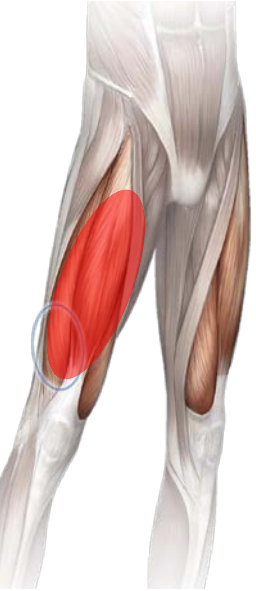
- Clinical impairments
- Outcomes with traditional rehabilitation
- Mechanisms of persistent muscle weakness
- Clinical strategies to overcome muscle inhibition

The Problem

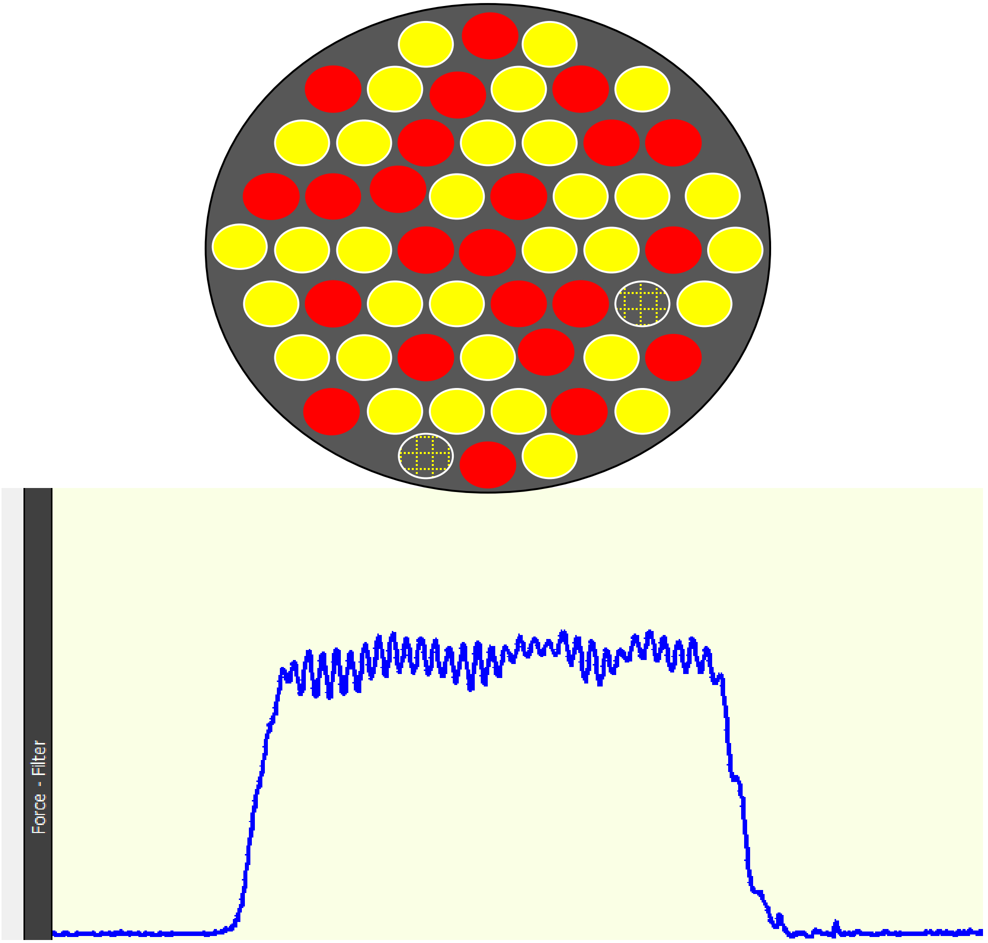
- 19 y/o football player
- Patellofemoral pain x 6 months



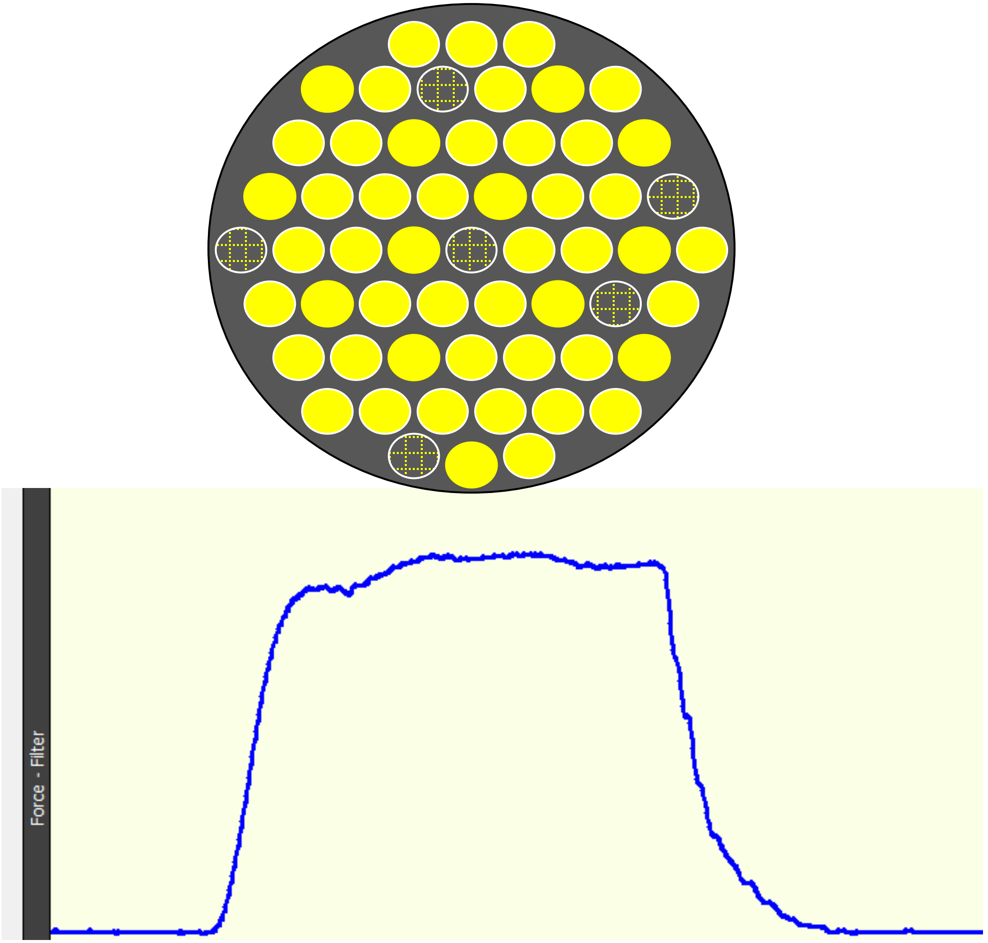
Altered Motor Neuron Recruitment



Inhibited Motor Neuron Pool



Healthy Motor Neuron Pool

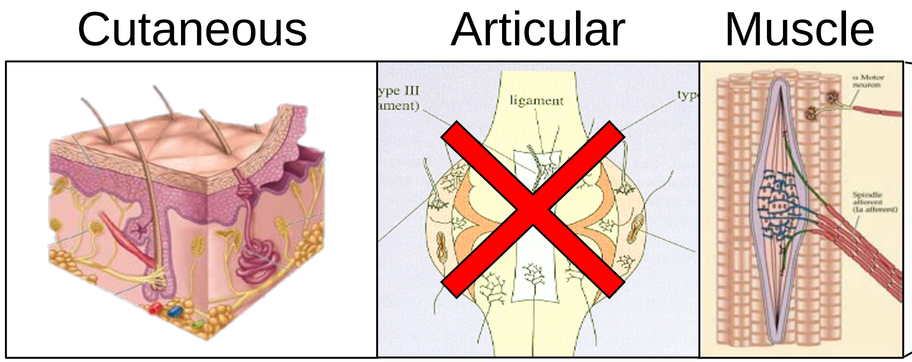


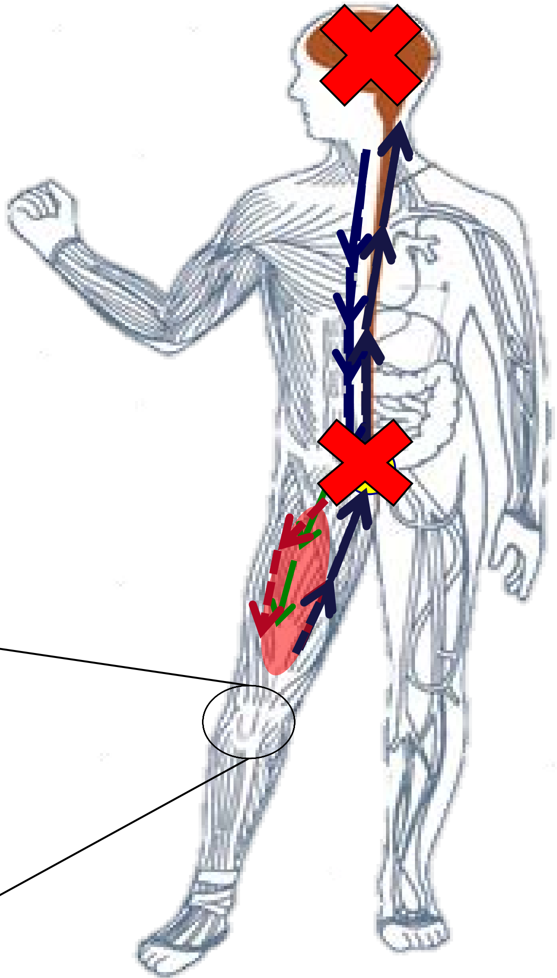
Healthy   Inhibited   Reserve

So…What's Preventing Full Recovery?

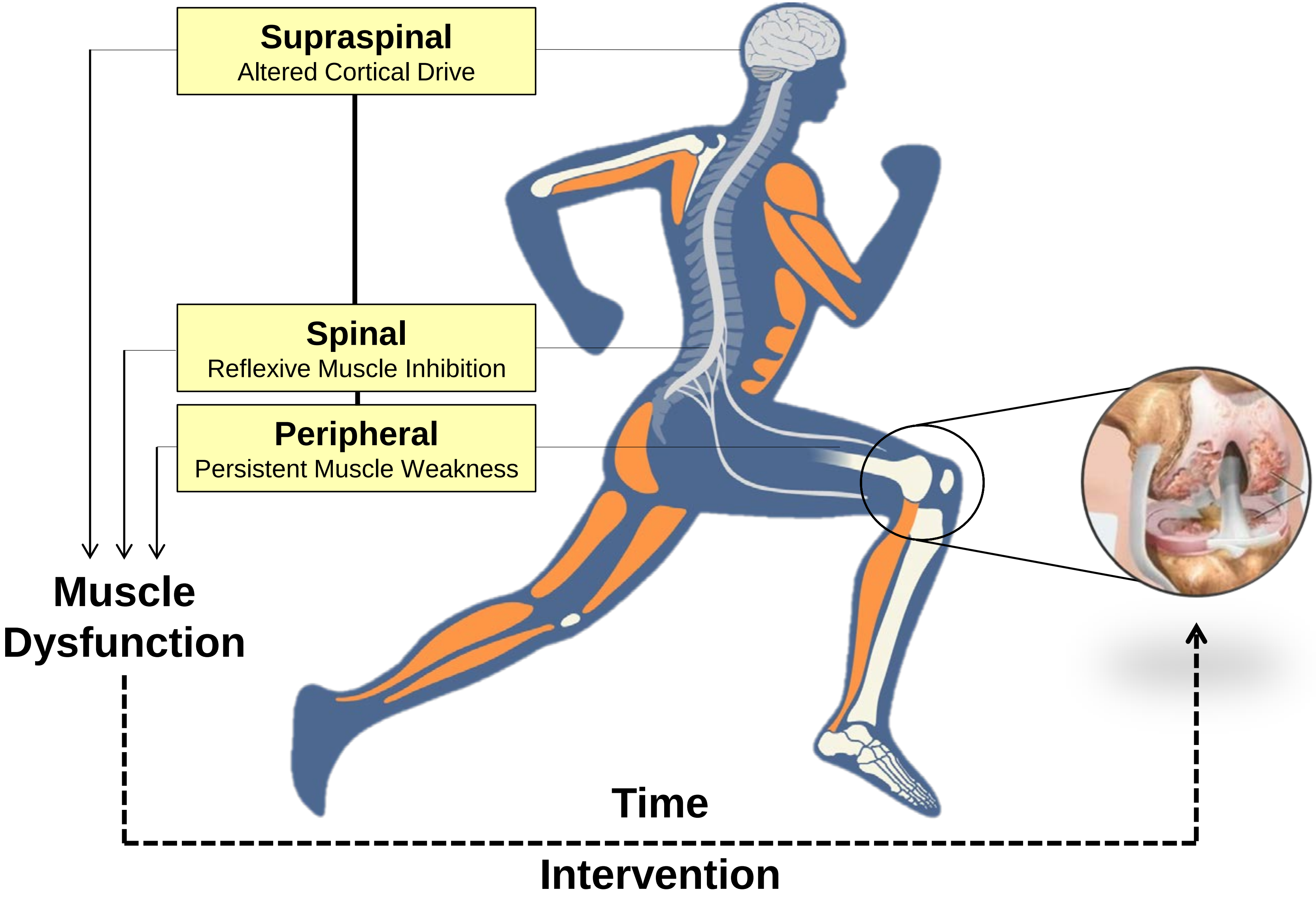
Origins of Neuromuscular Adaptation

- **Altered afferent stimuli from joint receptors transmitted to spinal cord** (de Andrade 1965, Stokes and Young 1984)



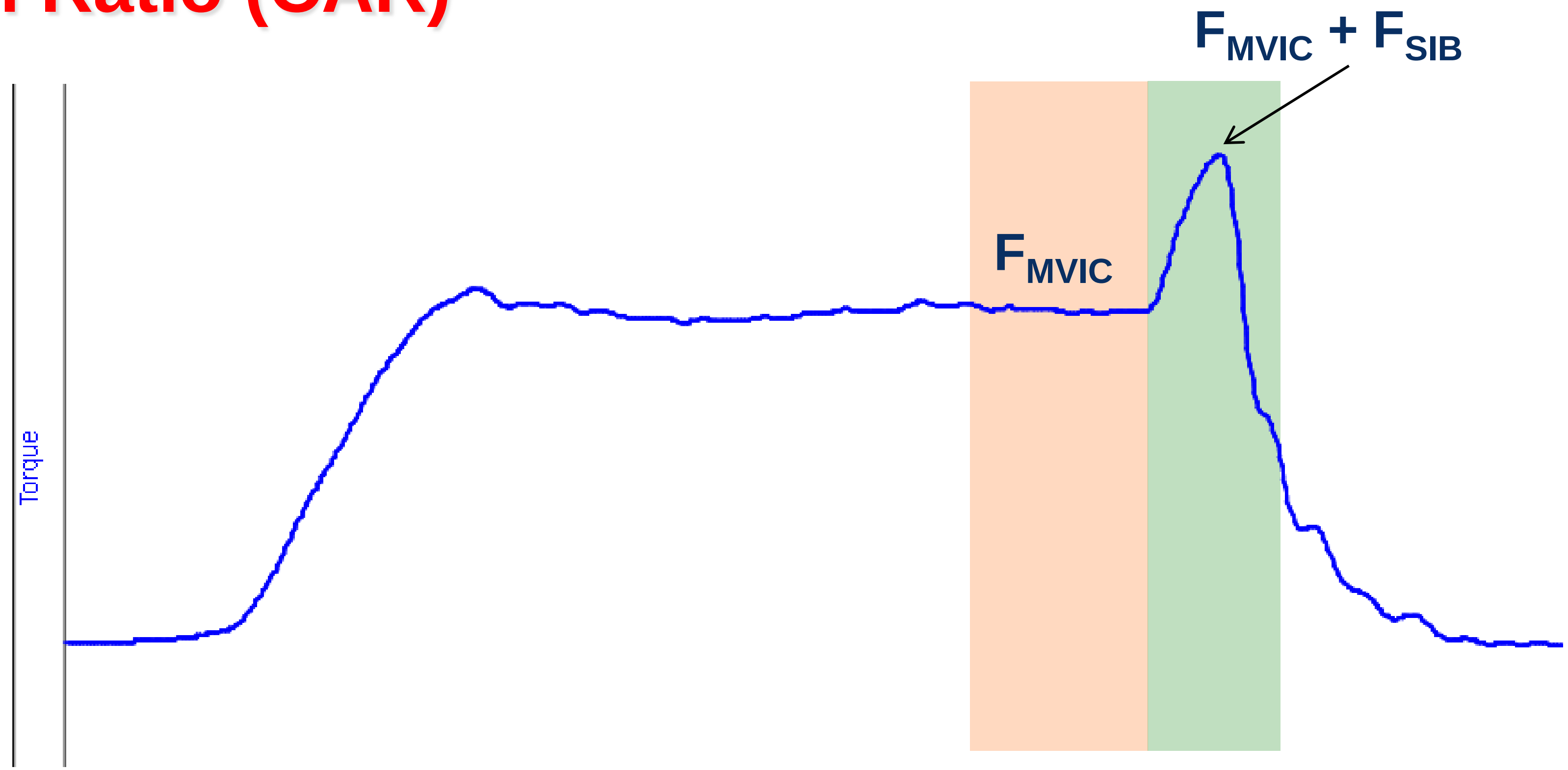


Proposed Neuromuscular Paradigm



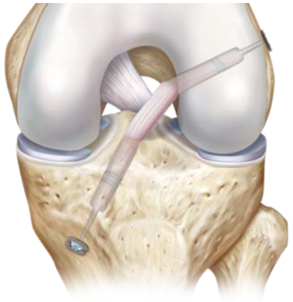
Measuring Central Activation Failure

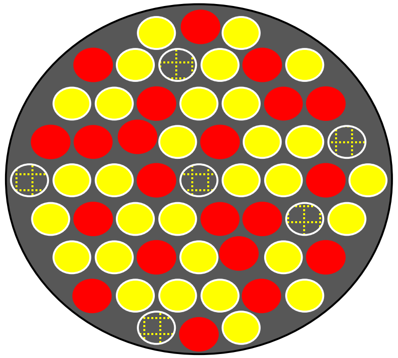
- **Central Activation Ratio (CAR)**

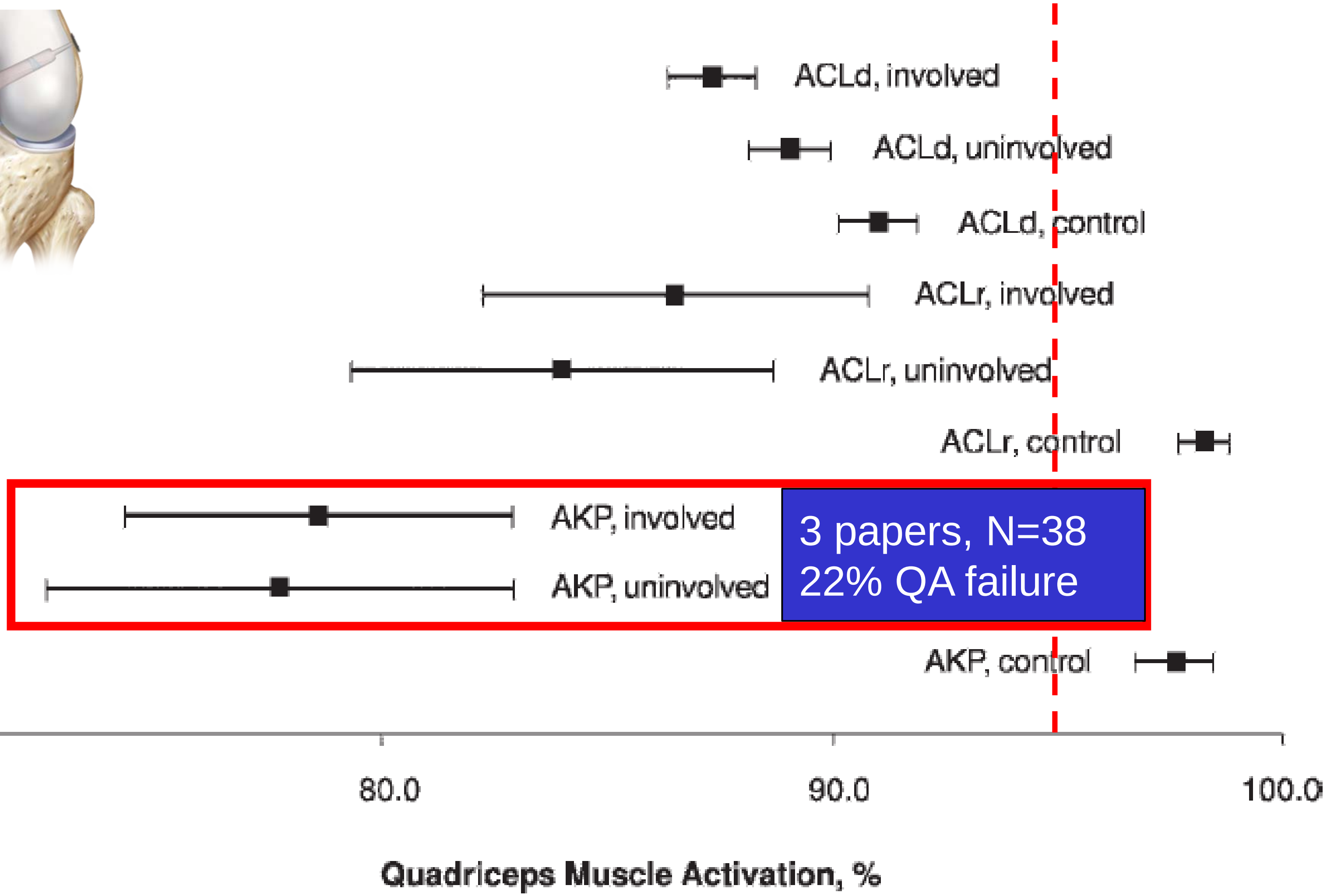


$$CAR = \frac{\text{Motor Neurons Activated } (F_{MVIC})}{\text{Total Motor Neurons Available } (F_{MVIC} + F_{SIB})}$$

Evidence of Central Activation Failure







Hart JM, et al. Quadriceps Activation Following Knee Injuries: A Systematic Review. *J Athl Train*. 2010

Impact of Central Activation Failure in PFP

- **While walking, patients with quadriceps CAF (~9%) demonstrate:**
  - ↓ peak vGRF
  - ↓ sagittal plane motion (knee, hip)
  - ↓ sagittal plane force generation (ankle, knee, hip)
  - ↑ frontal plane motion (ankle)

Similar pain, subjective function, psychological function, and activity level!

- **Impact of decreased knee loading?**
  - Increased collagen breakdown relative to synthesis (Pietrosimone 2016)
- **Inability to accept and generate force (stiff gait)**
  - Risk factor for development of PFP (Boling 2009)

Seeley MK, Son SJ, Kim H, Hopkins JT. Walking mechanics for patellofemoral pain subjects with similar self-reported pain levels can differ based upon neuromuscular activation. *Gait Posture*. 2017

A Vicious Cycle?

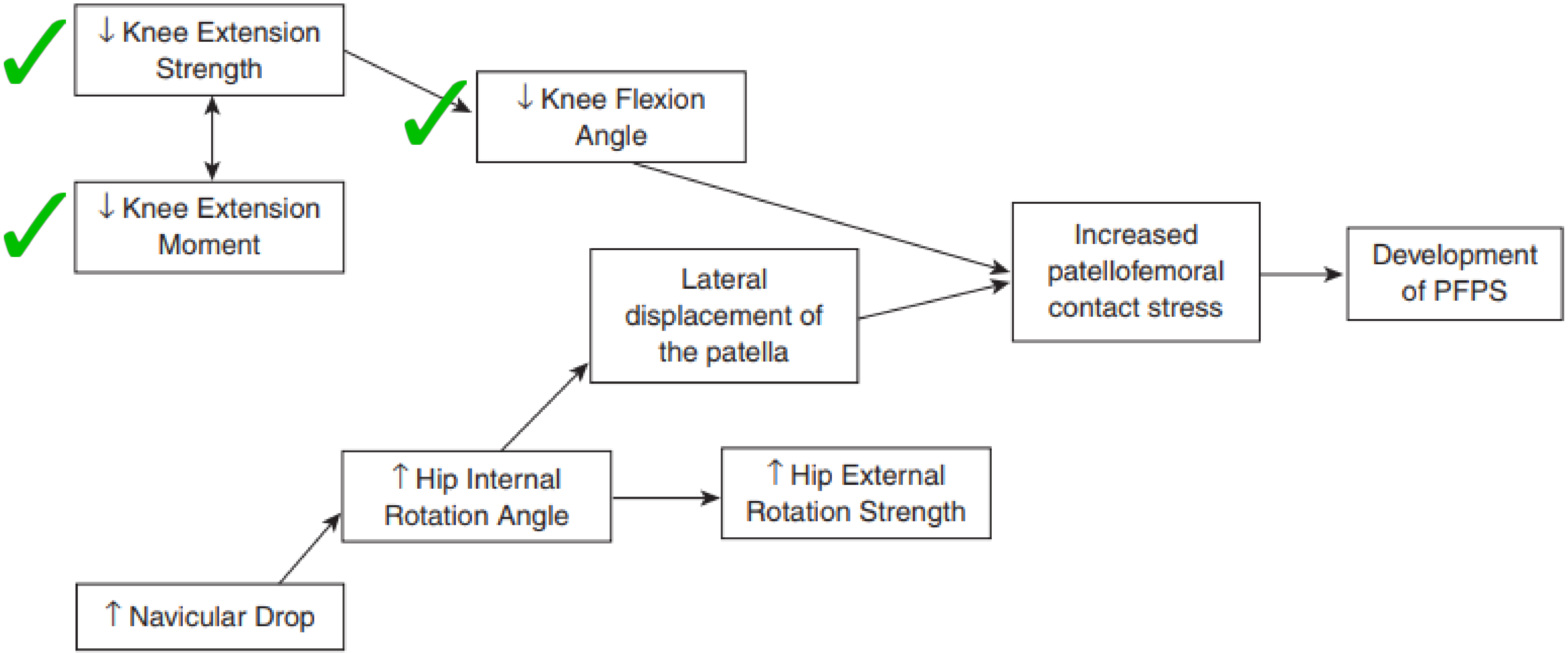
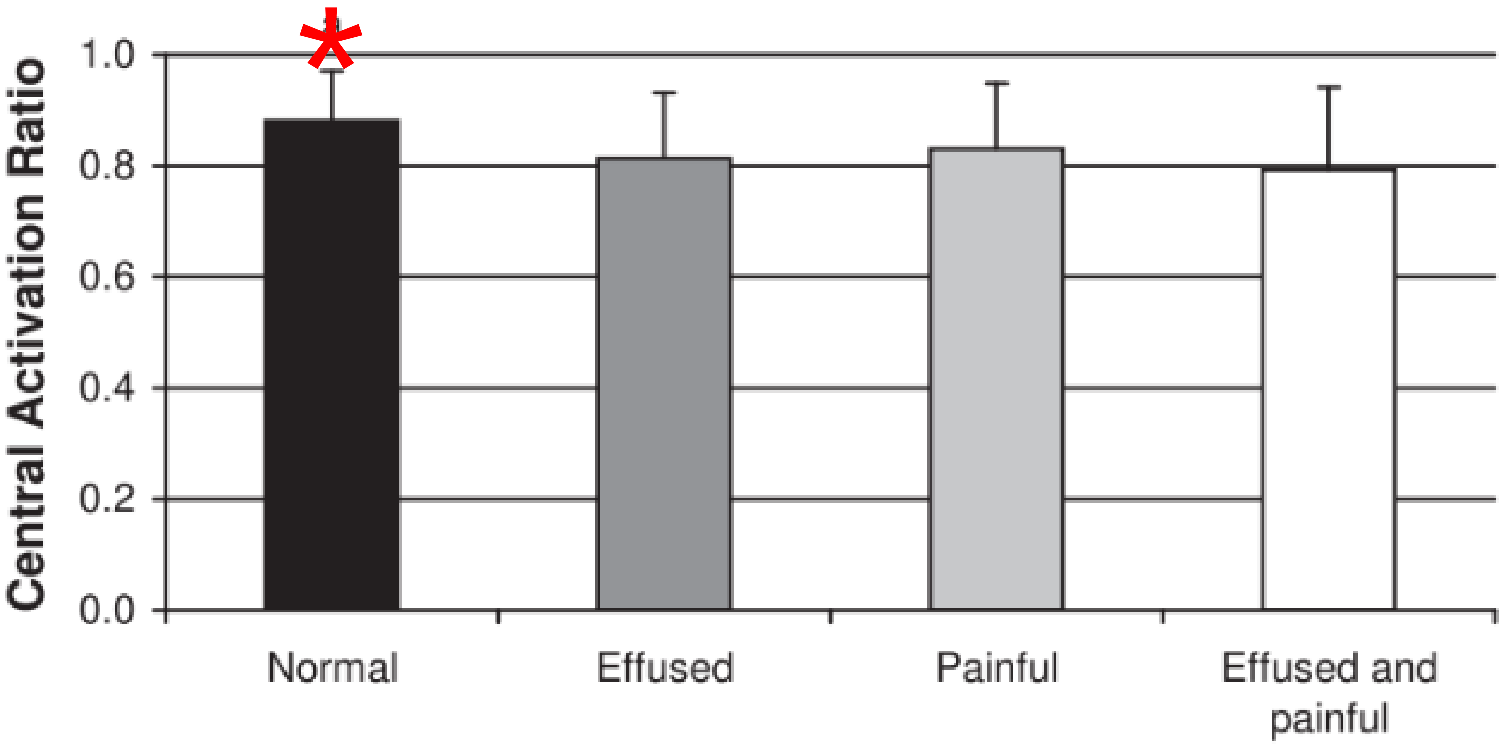


Figure 1. Conceptual model for the development of patellofemoral pain syndrome.

Boling MC, Padua DA, Marshall SW, Guskiewicz K, Pyne S, Beutler A. A prospective investigation of biomechanical risk factors for patellofemoral pain syndrome. *Am J Sports Med*. 2009

Causes of Muscle Inhibition

- **Effusion and pain independently decrease the ability to voluntarily recruit motor neurons (central activation failure)**

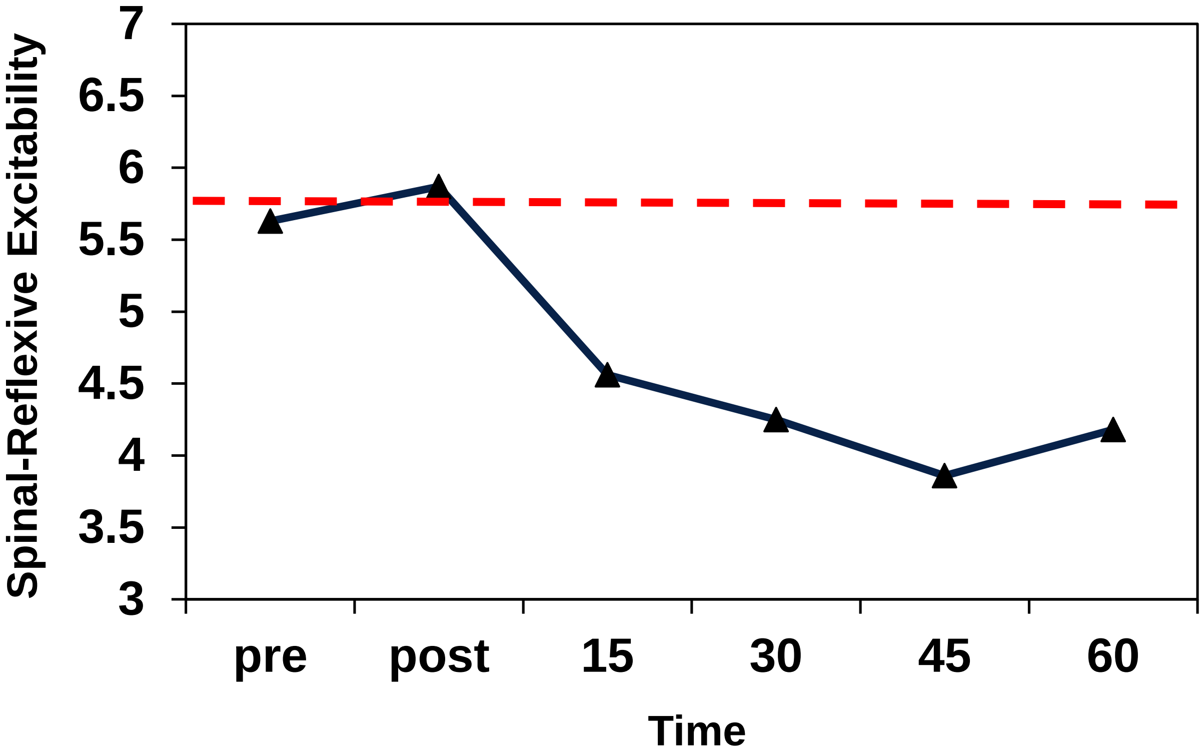


Palmieri-Smith RM, et al. Pain and Effusion and Quadriceps Activation and Strength. *J Athl Train*. 2013

Park J and Hopkins JT. Induced anterior knee pain immediately reduces involuntary and voluntary quadriceps activation. *Clin J Sports Med*. 2013

Causes of Muscle Inhibition: Spinal

- **Effusion and pain independently decrease the potential to recruit motor neurons (reflexive inhibition)**

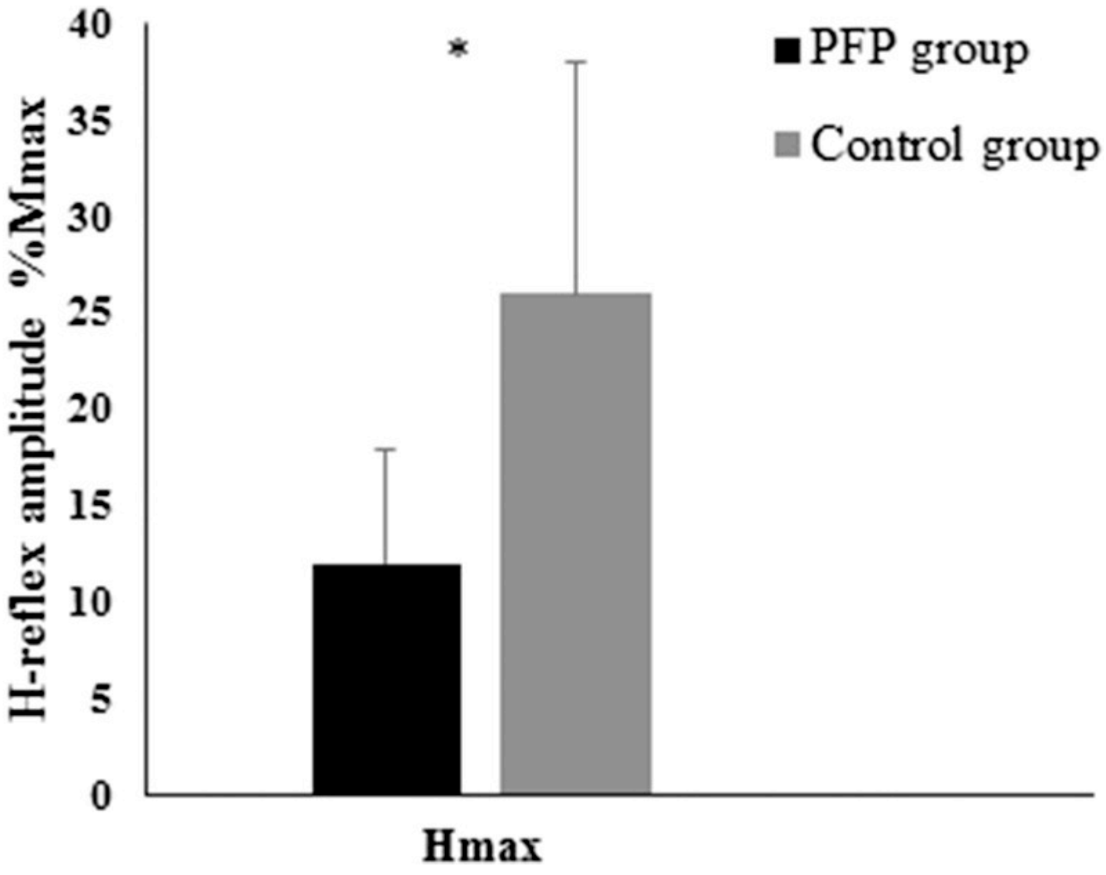


Hopkins JT, et al. Cryotherapy and TENS decrease arthrogenic muscle inhibition of the Vastus Medialis following knee joint effusion. *J Athl Train*. 2001

Park J and Hopkins JT. Induced anterior knee pain immediately reduces involuntary and voluntary quadriceps activation. *Clin J Sports Med*. 2013

Neurological Changes with PFP: Spinal

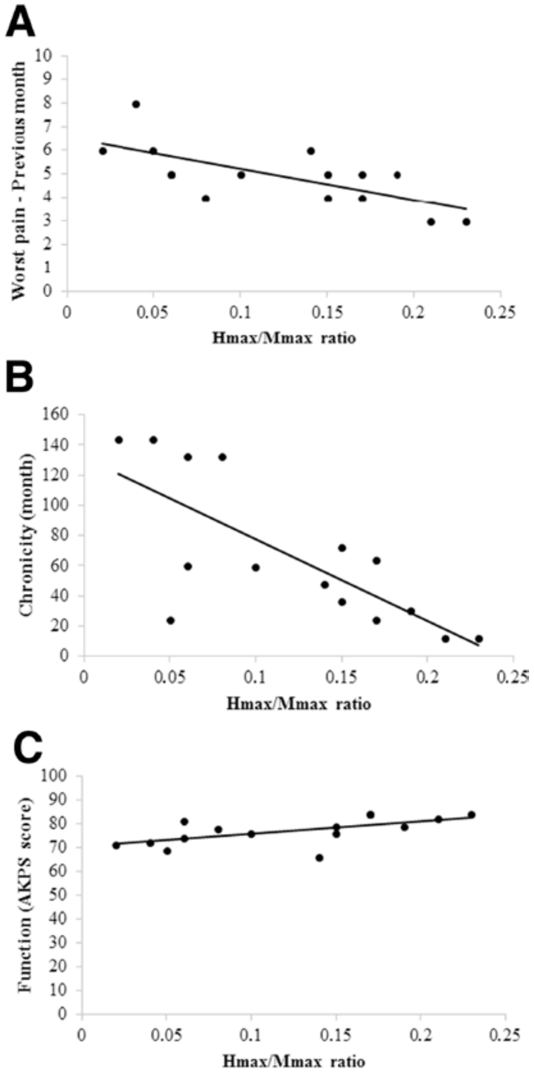
- **Adult women with PFP (n = 15)**
- **Healthy controls (n = 15)**
- **Conclusions:**
  – 14% decrease in quadriceps spinal-reflexive excitability with PFP compared to healthy
  – 73% of patients demonstrated reduced excitability



de Oliveira Silva D, et al. Lower amplitude of the Hoffmann reflex in women with patellofemoral pain: thinking beyond proximal, local, and distal factors. *Arch Phys Med Rehabil*. 2016

Implications of Neurological Changes

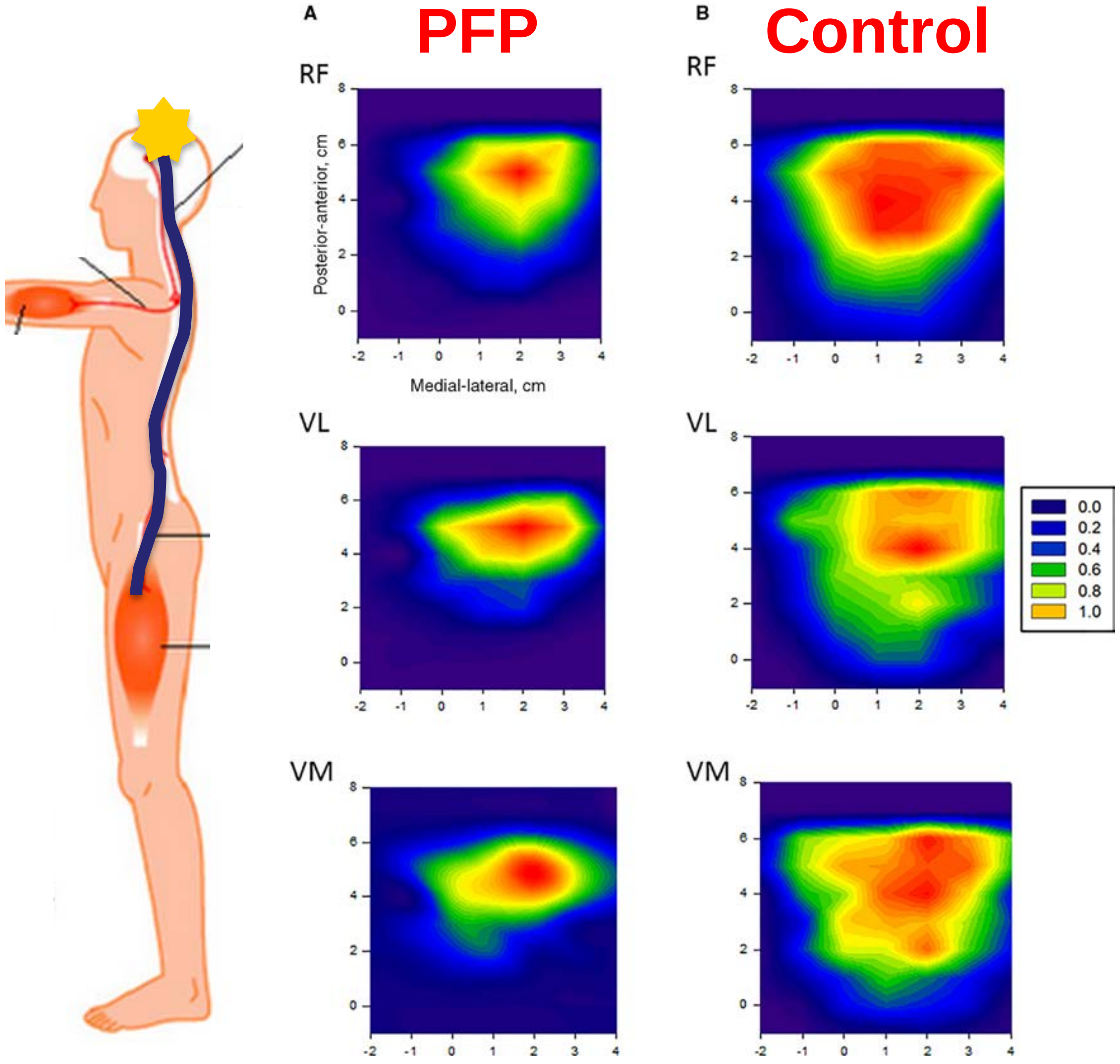
- **Adult women with PFP (n = 15)**
- **Conclusions:**
  - Patients with lower quadriceps spinal-reflexive excitability also had:
    - A. Higher knee pain (*r* = -0.71)
    - B. Longer duration of symptoms (*r* = -0.74)
    - C. Worse self-reported physical function (*r* = 0.62)
- **Clinical Implications:**
  - Interventions designed to enhance quadriceps spinal-reflexive excitability should be considered



de Oliveira Silva D, et al. Vastus medialis Hoffmann reflex excitability is associated with pain level, self-reported function, and chronicity in women with patellofemoral pain. *Arch Phys Med Rehabil*. 2017

Neurological Changes with PFP: Brain

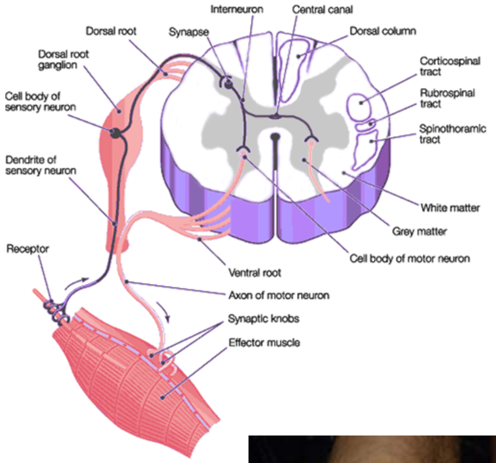
- **PFP (n = 11)**
- **Healthy (n = 11)**
- **Conclusions:**
  – Decreased quadriceps map volume of primary motor cortex in PFP compared to healthy
- **Clinical Implications:**
  – Reduced corticomotor excitability
  – Less cortical representation
  – Simplified movement strategies

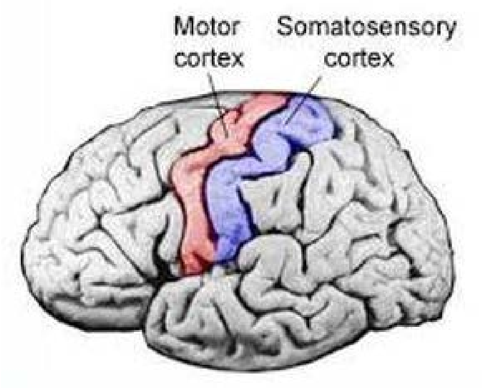


Te M, et al. Primary motor cortex organization is altered in persistent patellofemoral pain. *Pain Medicine*. 2017

Neural Adaptations after ACLR

- **Early neural adaptation**
- **Late neural adaptation**



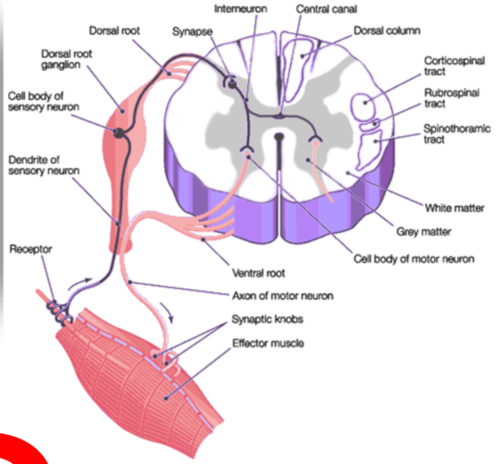


Decreased swelling, inflammation, pain

Lepley AS et al. Quadriceps neural alterations in anterior cruciate ligament reconstructed patients: a 6-month longitudinal investigation. *Scand J Med Sci Sports*. 2015

Neural Adaptations with PFP

- **Early neural adaptation**



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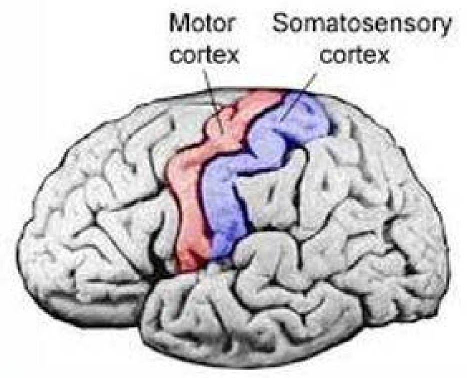
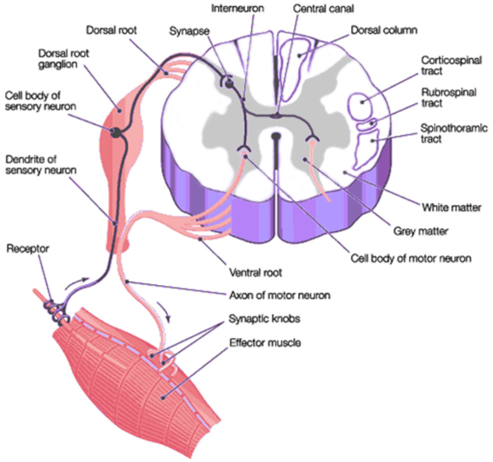
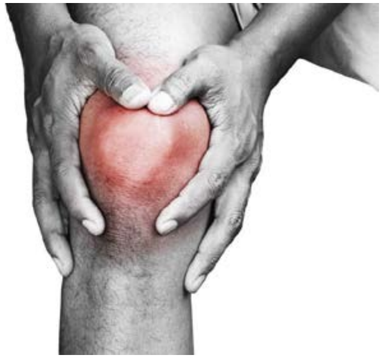
- **Late neural adaptation**







Persistent pain and inflammation

Voluntary Central Activation Failure

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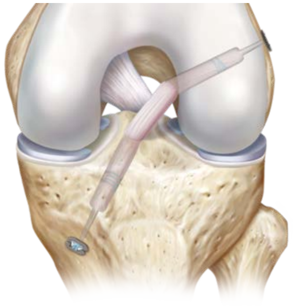
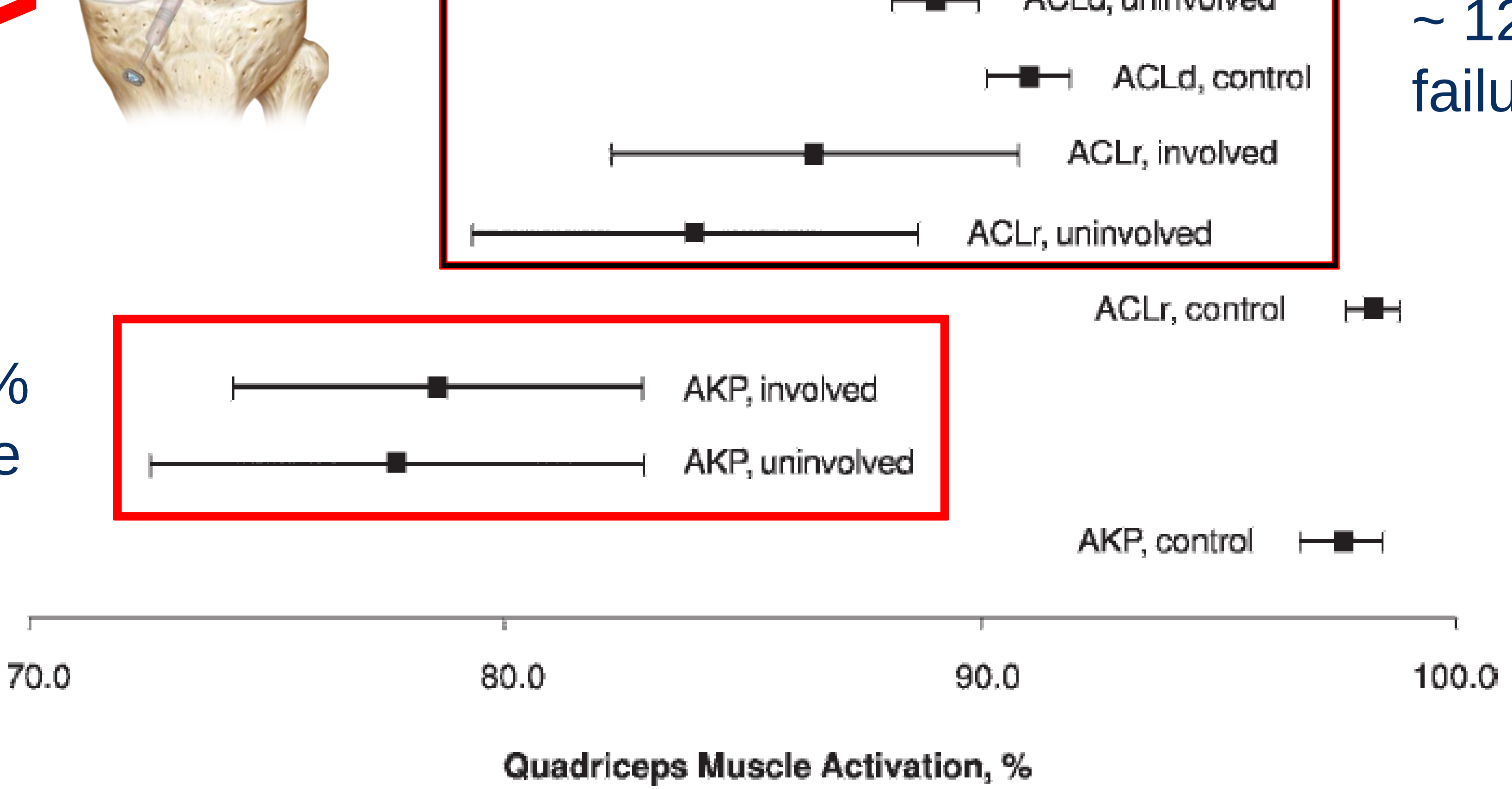


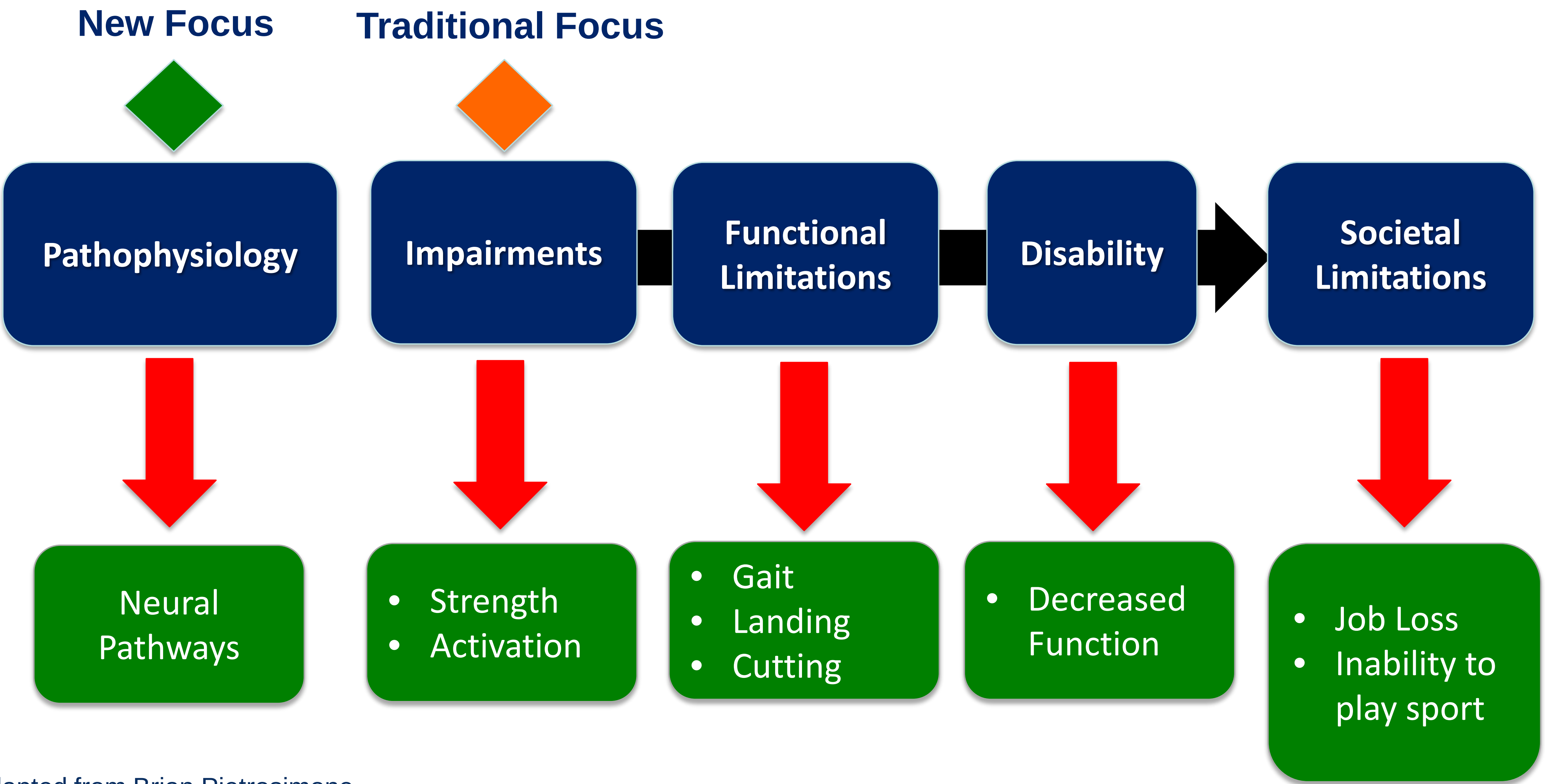


~ 12% failure

~ 22% failure

Hart JM, et al. Quadriceps Activation Following Knee Injuries: A Systematic Review. *J Athl Train*. 2010

Paradigm Shift in Treating Muscle Inhibition



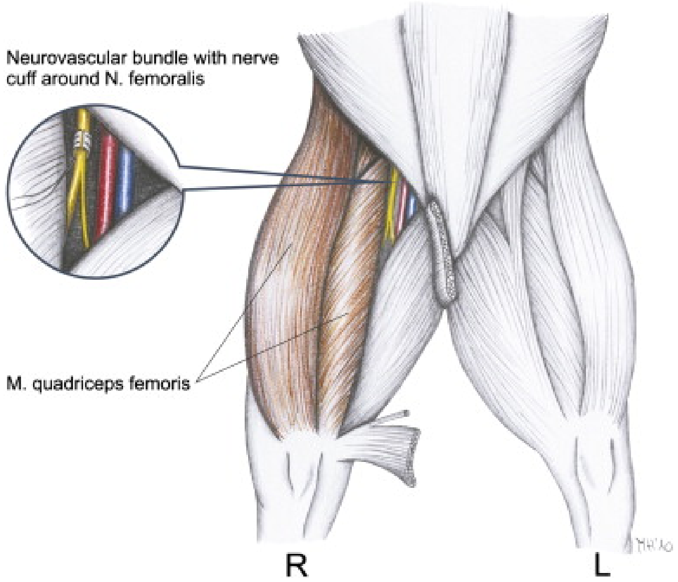
Slide adapted from Brian Pietrosimone

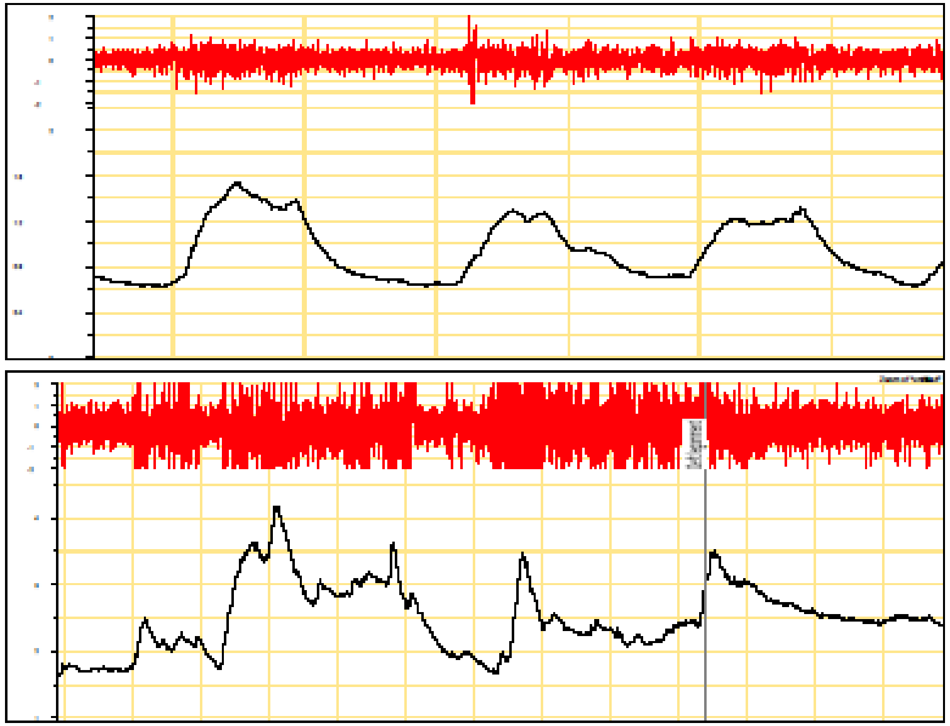
Overcoming Muscle Inhibition

- Turn down the “noise”
- Turn up other “noise”

Evidence of Too Much "Noise"

- **ACL Reconstruction**
  - Higher magnitude sensory response to knee joint movement vs. contralateral side



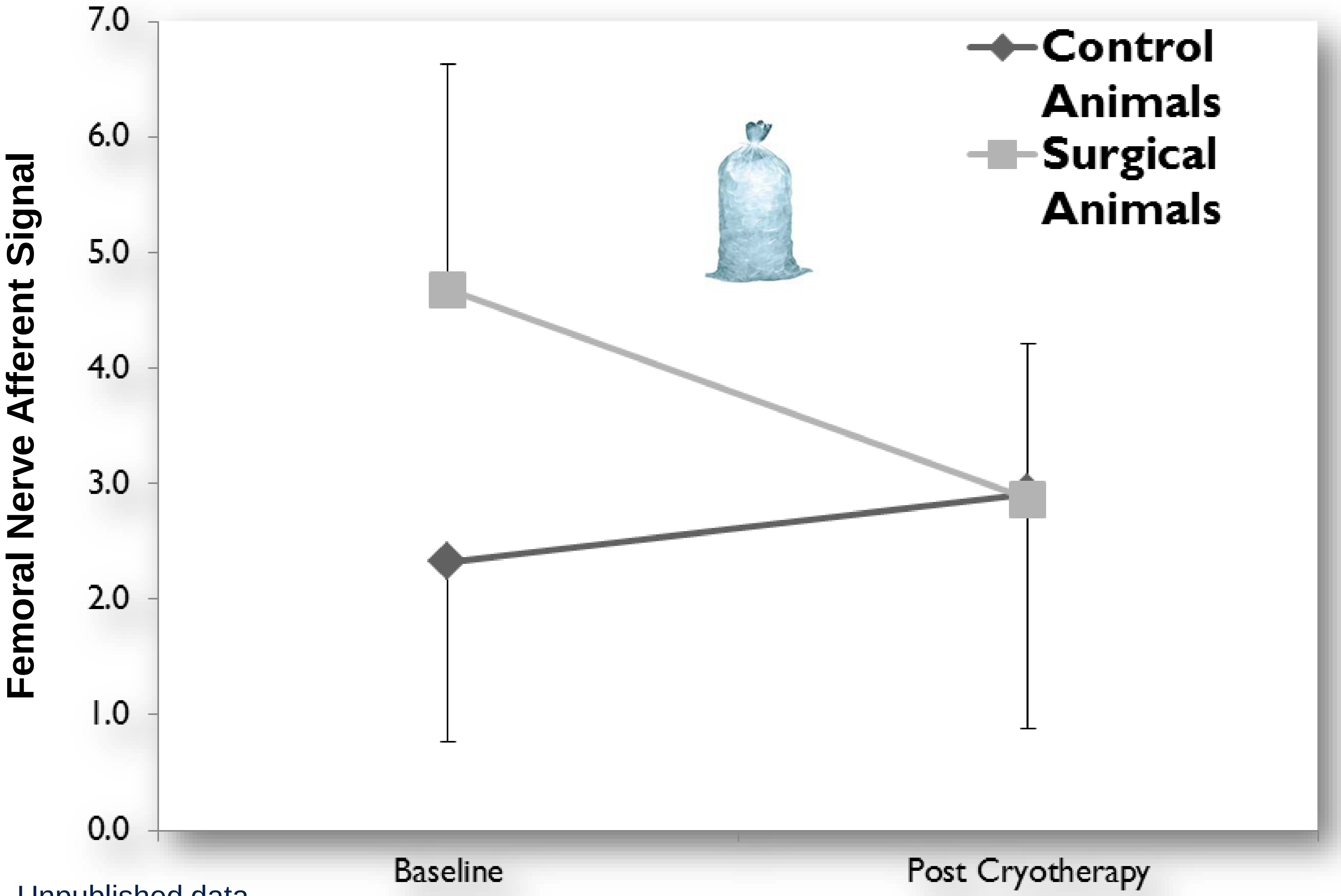


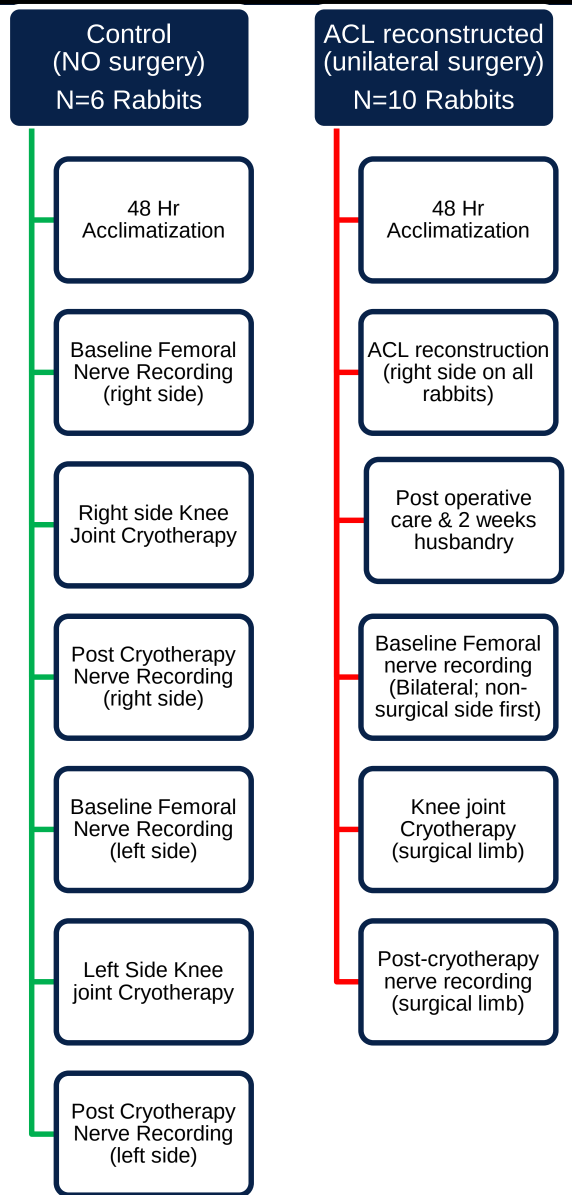
Control Limb

ACLR Limb

Hart et al. Sensory Response Following Knee Joint Damage in Rabbits. BMC Musculoskelet Disord. 2014

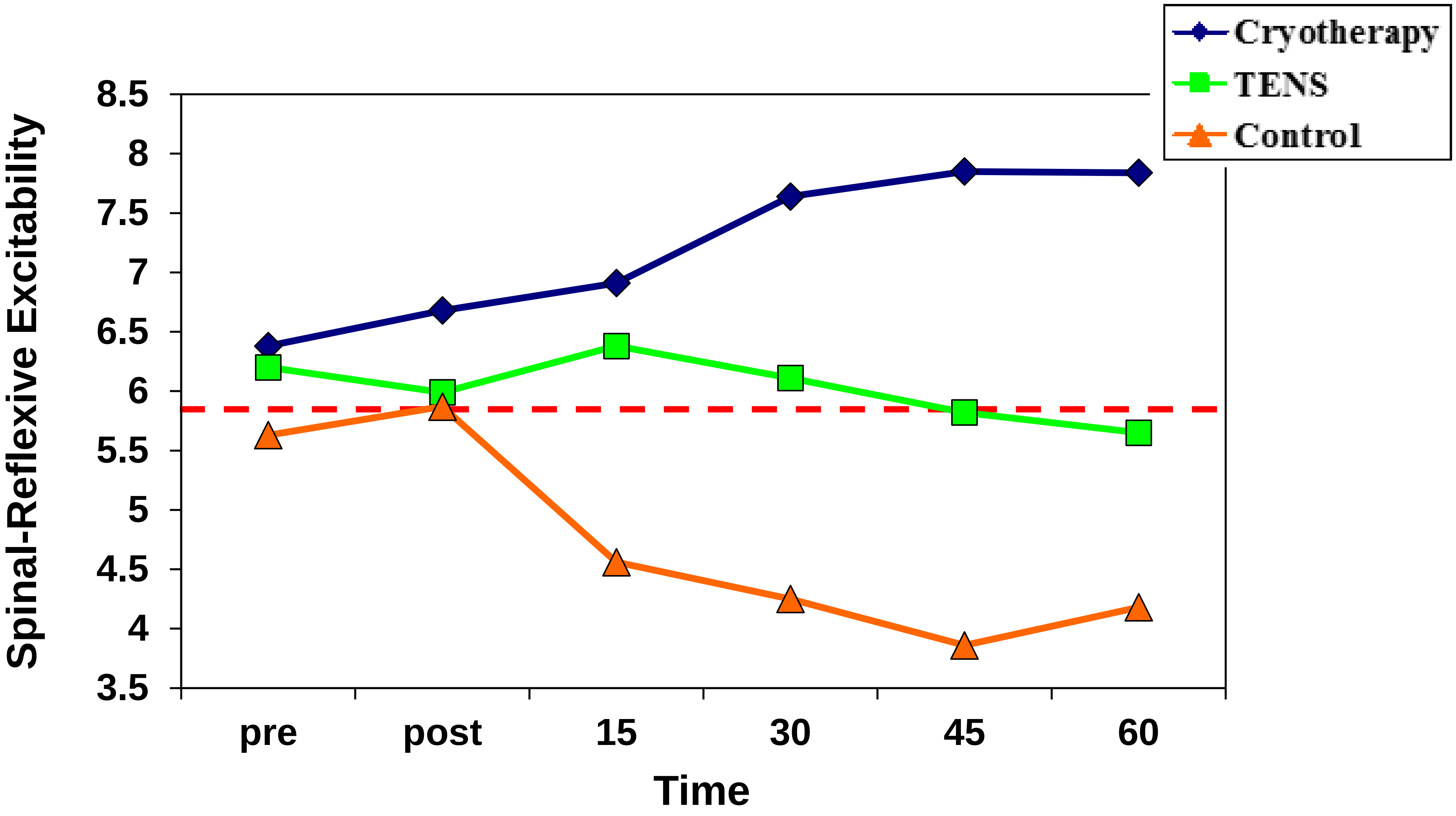
Can "Noise" Be Modulated?

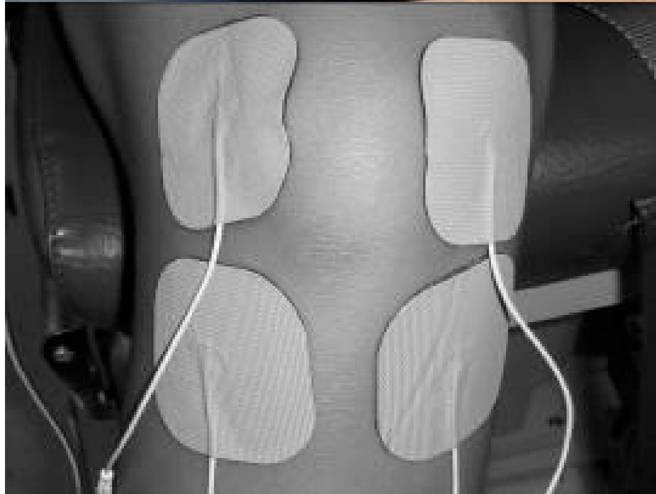




Hart JM. Unpublished data

"Dis-inhibitory" Therapies





Hopkins JT, Ingersoll CD, Krause BA, Edwards JE, Cordova ML. Cryotherapy and TENS decrease arthrogenic muscle inhibition of the Vastus Medialis following knee joint effusion. *J Athl Train*. 2001

Learning Objectives

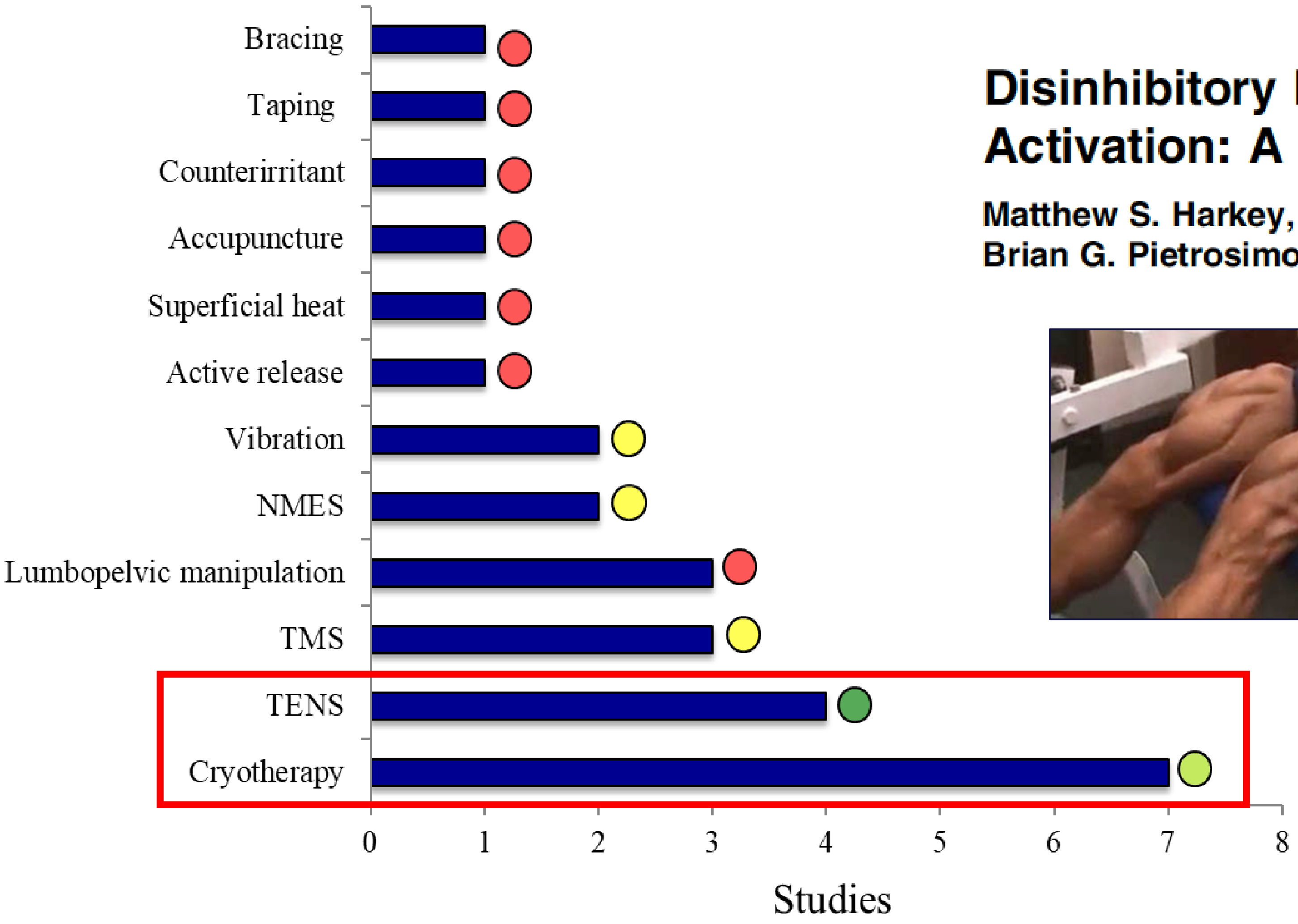
- Clinical impairments
- Outcomes with traditional rehabilitation
- Mechanisms of persistent muscle weakness
- Clinical strategies to overcome muscle inhibition

How Can We Treat These Patients?

- **Compliments to traditional rehabilitation**
  - TENS
  - Cryotherapy
  - Biofeedback
  - NMES
  - Taping
  - Blood flow restriction

Neural Impairments

Treating Neural Impairments



Journal of Athletic Training 2014;49(1):000–000
doi: 10.4085/1062-6050-49.1.04

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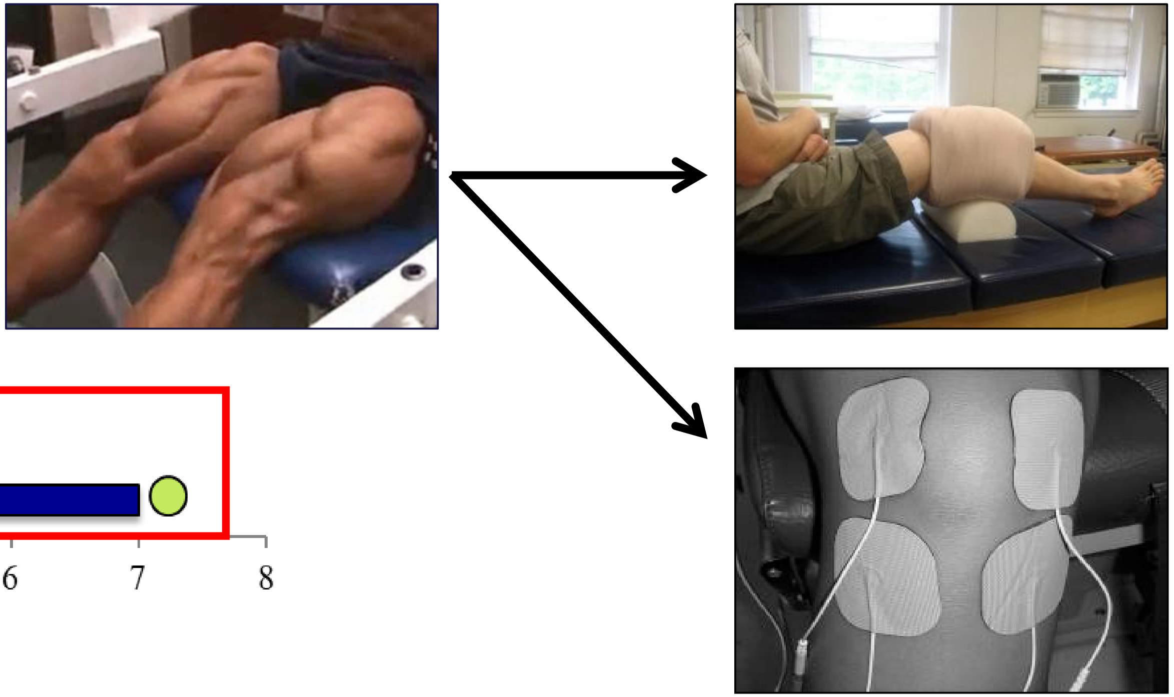
systematic review

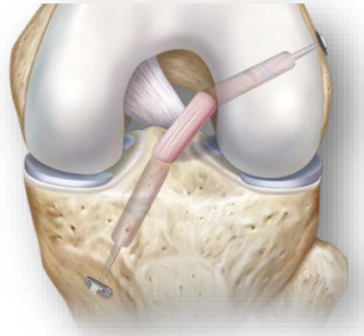
Disinhibitory Interventions and Voluntary Quadriceps Activation: A Systematic Review

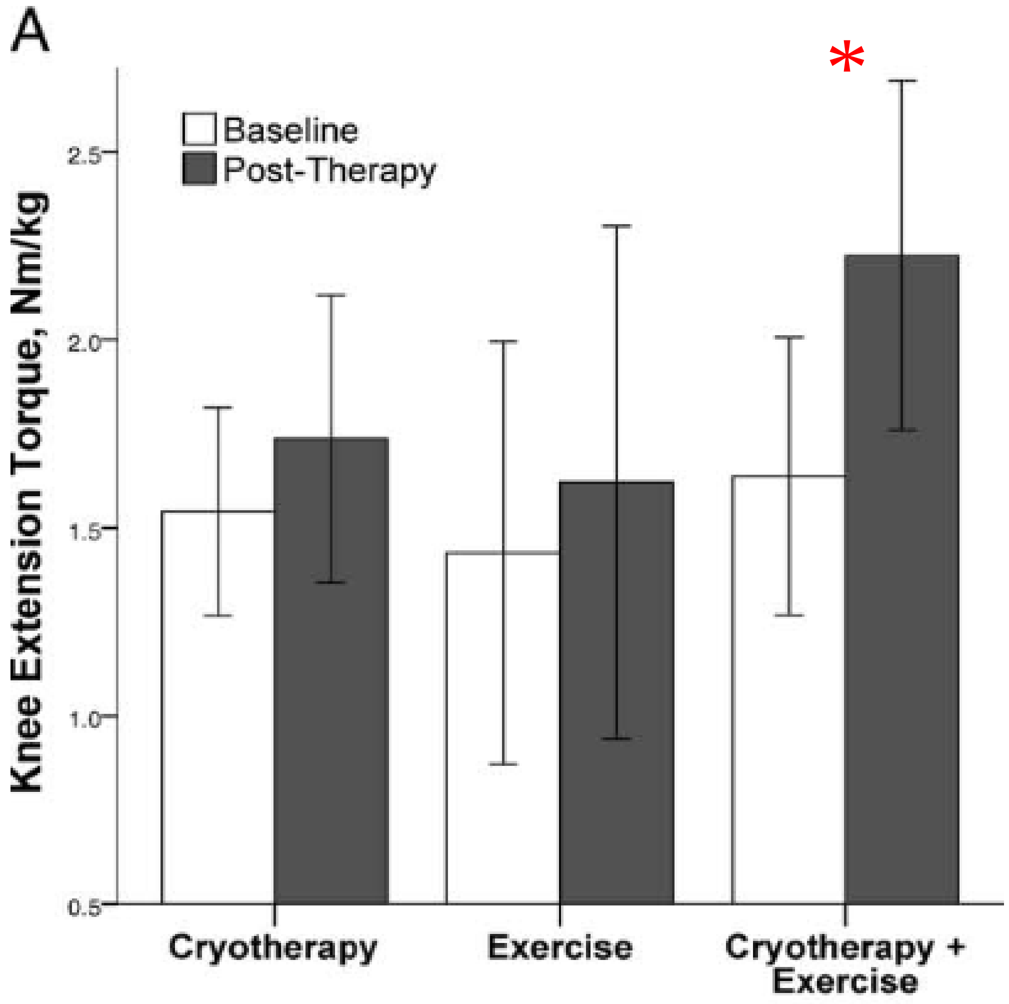
Matthew S. Harkey, MS, ATC*; Phillip A. Gribble, PhD, ATC, FNATA*; Brian G. Pietrosimone, PhD, ATC*



Cryotherapy

- **30 ACL reconstructed patients**
- **2-week intervention**
  - Cryotherapy
  - Exercise
  - Cryotherapy + exercise

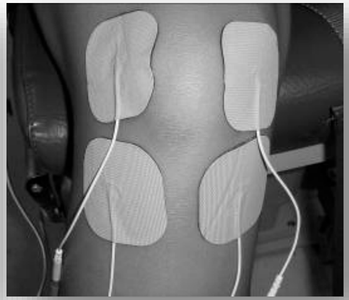


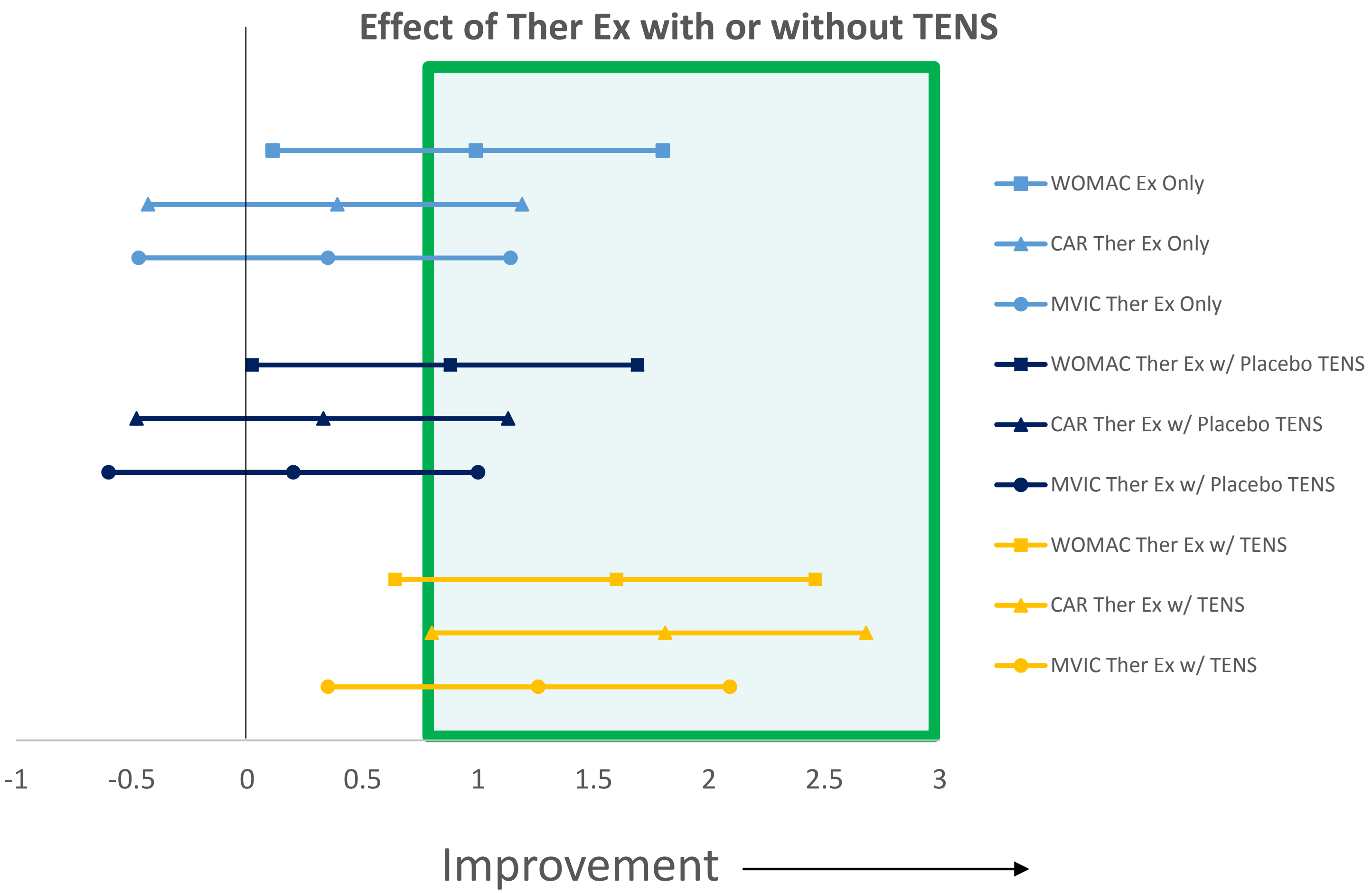


Hart et al. Quadriceps muscle function after rehabilitation with cryotherapy in patients with anterior cruciate ligament reconstruction. J Athl Train. 2014

TENS

- **36 patients with tibiofemoral OA**
- **4-week intervention**
  - Exercise
  - Exercise + placebo TENS
  - Exercise + TENS

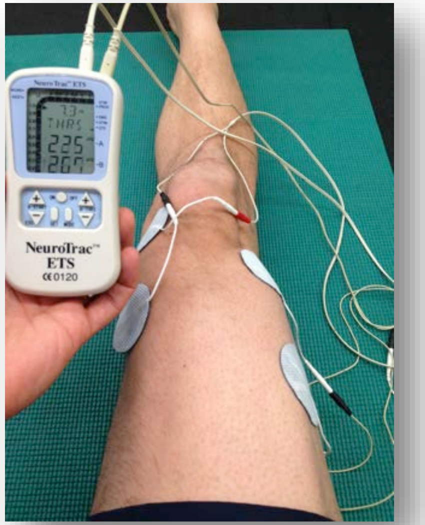


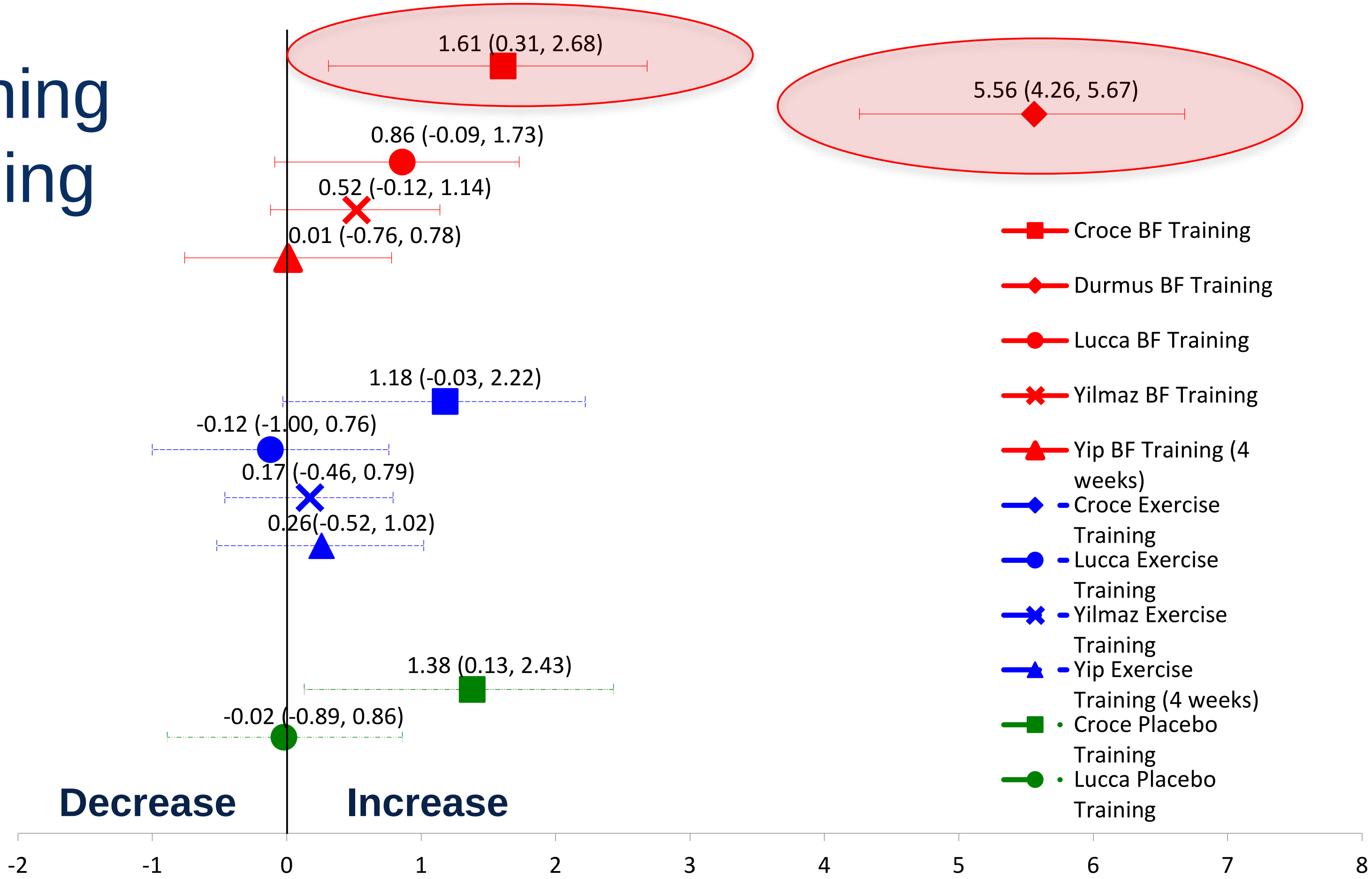


Pietrosimone et al. Effect of Transcutaneous Electrical Nerve Stimulation and Therapeutic Exercise on Quadriceps Activation in People with Tibiofemoral Osteoarthritis. J Orthop Sports Phys Ther. 2011

EMG Biofeedback

- **Effects of EMG-BF on quadriceps strength**
  - EMG-BF
  - Exercise Training
  - Placebo Training

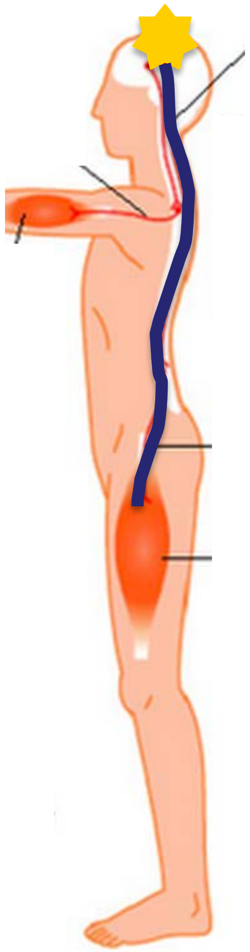




Lepley et al. Effects of Electromyographic Biofeedback on Quadriceps Strength: A Systematic Review. J Strength Cond Res. 2012

EMG Biofeedback

- **Corticomotor excitability (MEP amplitude)**
  - **EMG biofeedback vs. control**
    - Pre (5% MVIC)
    - Post (100% MVIC)
  - **Findings**
    - EMG-BF increased corticomotor excitability
    - EMG-BF increased quadriceps strength



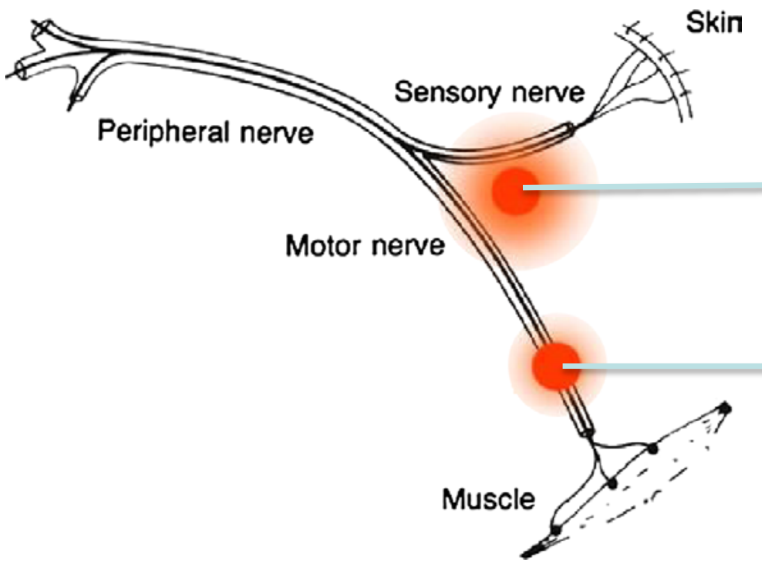
Pietrosimone et al. Immediate increases in quadriceps corticomotor excitability during an electromyography biofeedback intervention. *J Electromyogr Kinesiol*. 2015

NMES

- **Stimulates the muscle directly**
  - Circumventing inhibited motor neuron pool
  - However, it may not affect the underlying muscle inhibition itself (Rice 2010)
- **Dose and position dependent**
  - Treating in a flexed position produces more optimal outcomes (Fitzgerald 2003, Snyder-Mackler 1991)
  - High-intensity, maximal tolerated stimulus (Glaviano 2016)
  - 60% MVIC to optimize treatment (Glaviano 2016)
  - Patient tolerance?

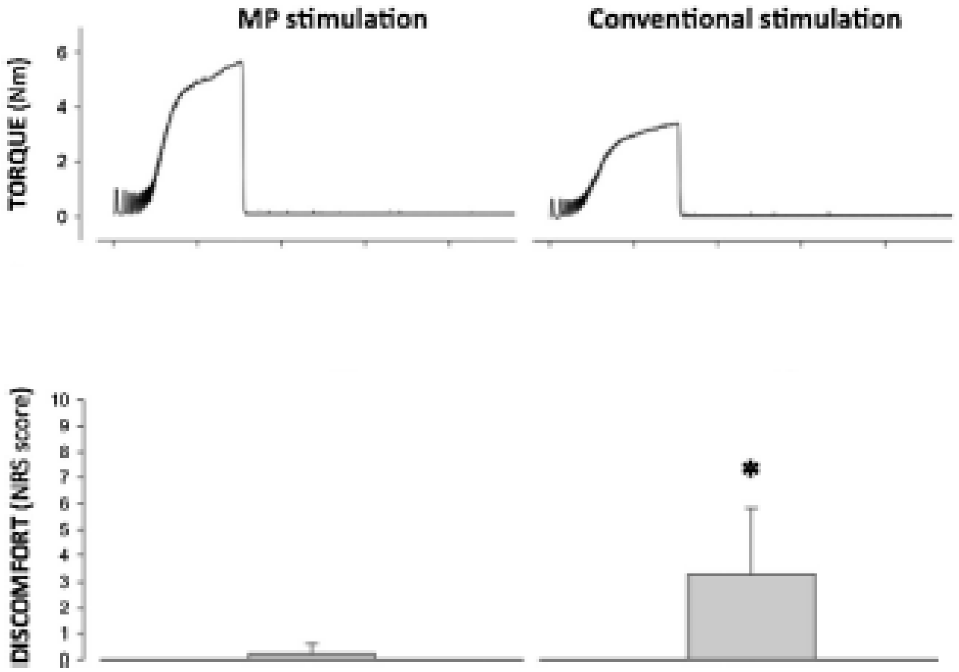
Improving NMES Use

- **Electrode should be over skeletal muscle motor point**
  - Transcutaneously evoke muscle twitch with lowest delivered current



Non-MP requires higher current intensity to produce contraction.
Also has greater excitation of sensory nerve fibers which can convey pain.

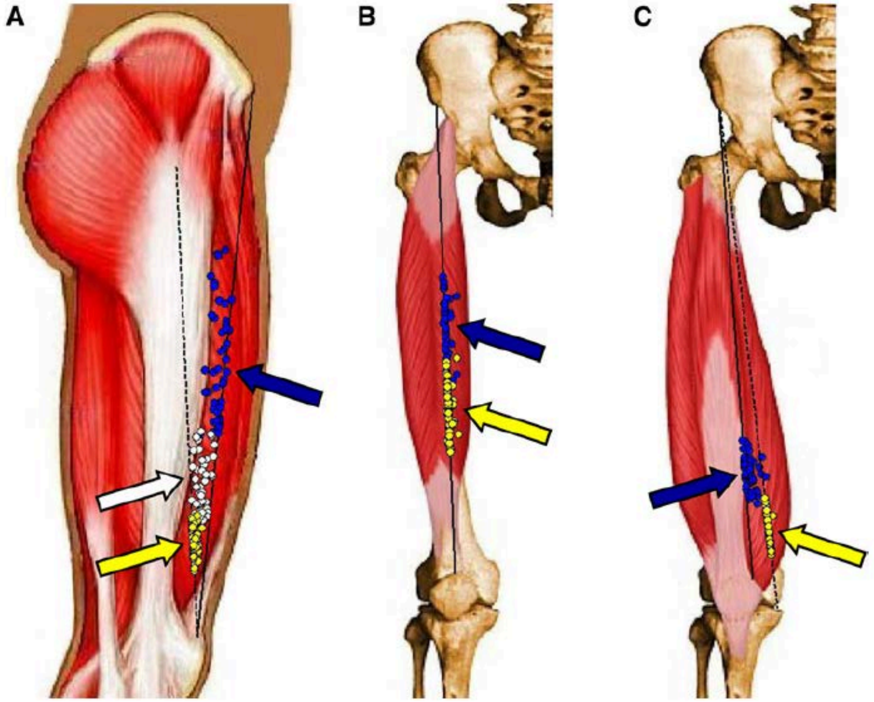
Less current needed to excite motor axon resulting in muscular contraction



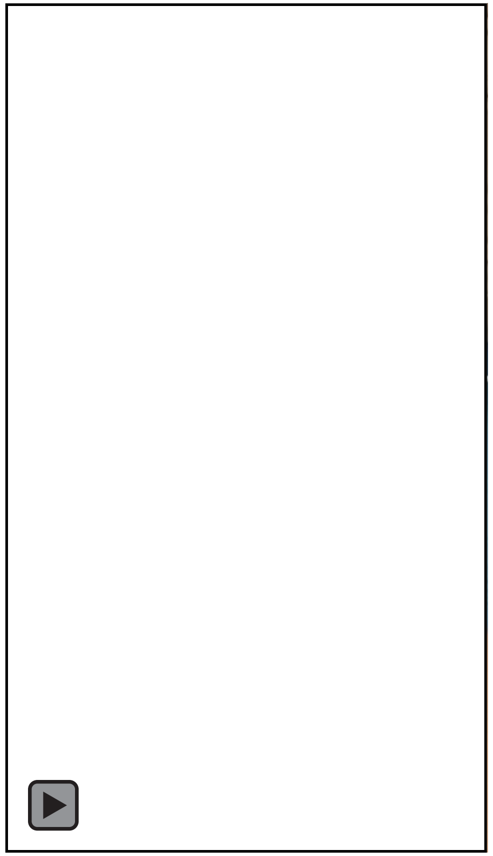
Gobbo 2011, 2014

Motor Point Identification

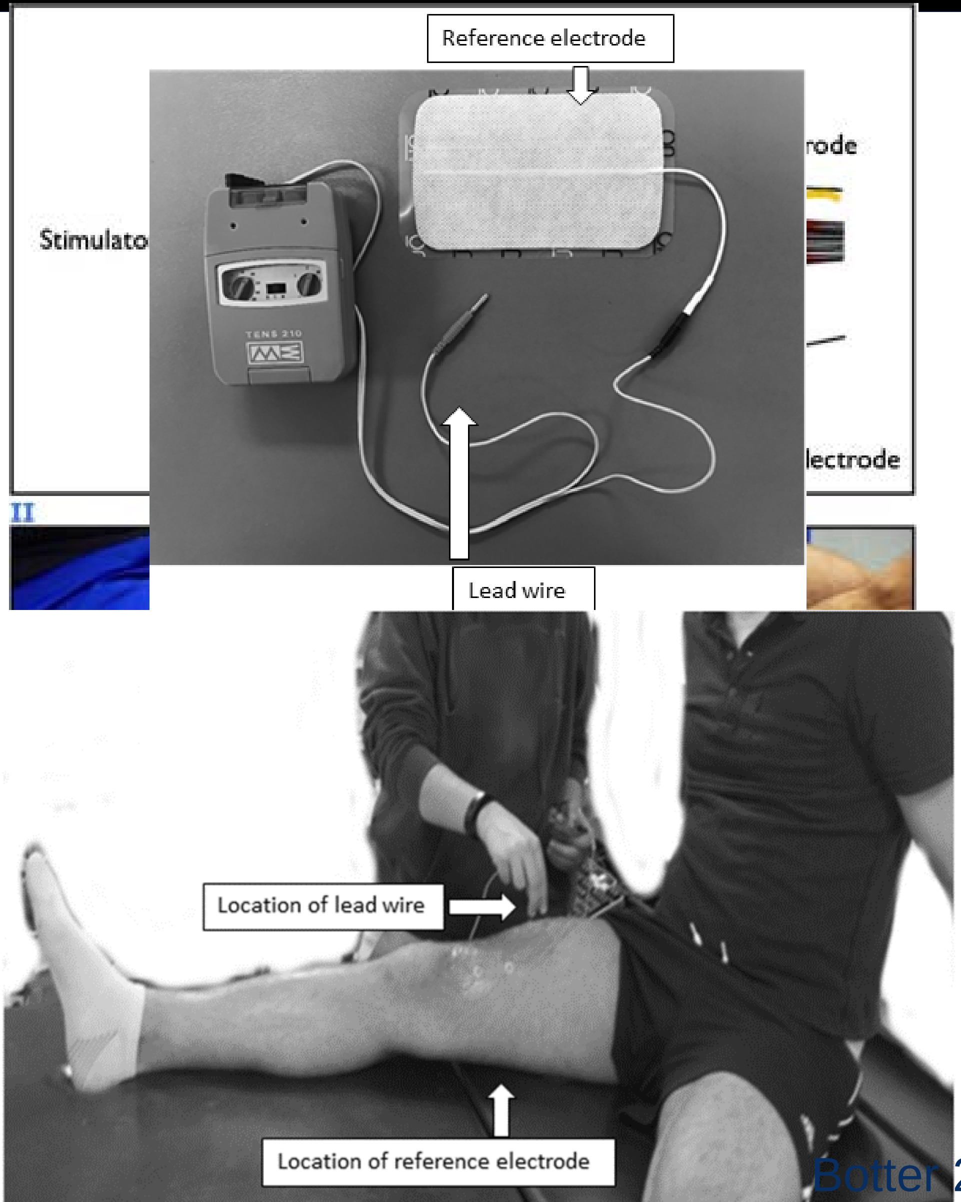
- **Quadriceps muscle motor point location vary between patients**



Botter 2011



Glaviano 2017



Botter 2014

Taping

- **Variety of applications and taping methods**
  - McConnell
    - Reduce immediate pain and improve function (Aminaka 2005)
      - Limited support for long-term pain relief
    - Recommended to not be used as isolated treatment (Balachandar 2011)
    - Must be tailored to patient to optimize pain reduction (Barton 2014)
      - Control lateral tilt, glide, and/or spin
  - Kinesio taping
    - No impact on pain, strength, balance, or proprioception (Aytar 2011)

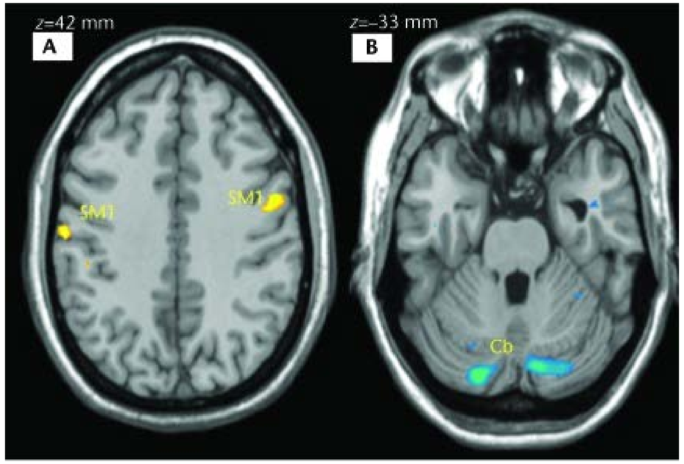
Taping

Effects of Patellar Taping on Brain Activity During Knee Joint Proprioception Tests Using Functional Magnetic Resonance Imaging

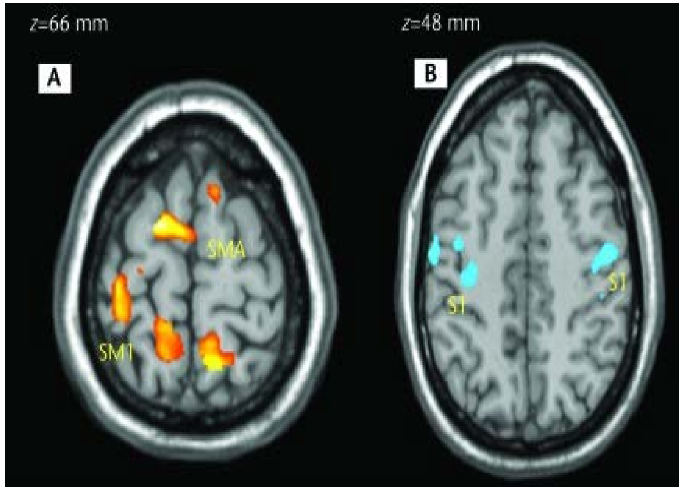
Michael J. Callaghan, Shane McKie, [...], and Jacqueline A. Oldham

- **4 fMRI scans**
  - Simple task & proprioception task with or without patellar tape
  - Brain activity during movement, proprioception, sensation, decision making for proprioception, and planning of complex coordination

Taping on both knee movements



Proprioception vs. simple task



Statistical significance in contrast to other conditions

High increase in activity

Small increase in activity

Negative activity

Low negative activity

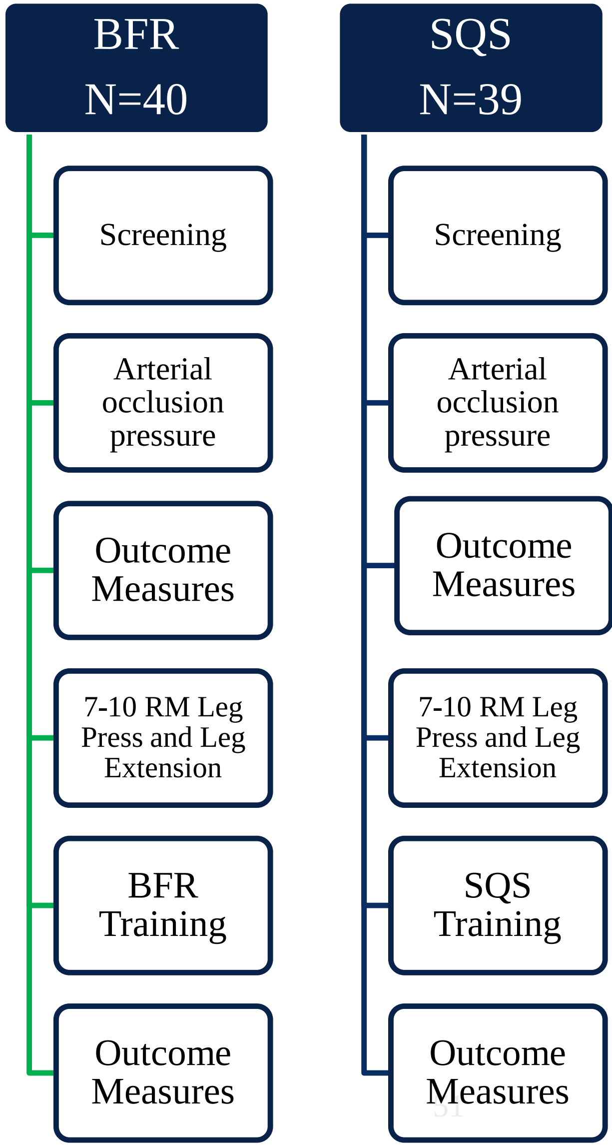
A= Taped Condition
B= No Tape

Blood Flow Restriction

Quadriceps strengthening with and without blood flow restriction in the treatment of patellofemoral pain: a double-blind randomised trial

Lachlan Giles, Kate E Webster, Jodie McClelland, Jill L Cook

- **Arterial Occlusion Pressure (AOP)**
  - **Pneumatic cuff on proximal thigh**
  - **Supine and pedal pulse located on US**
    - Cuff increased until no pulse (250mm/Hg max)
    - AOP recorded when pulse restored
    - BFR performed at 60% of AOP
- **Outcome measures (Pre, 8-wks, 6months)**
  - **Knee extension strength**
  - **Muscle thickness (US)**
  - **Pain (VAS)**
    - Worst in past week
    - Pain with activities (squatting, stairs, sitting)



Blood Flow Restriction

Identify 7-10 repetition maximum load

Multiply by the number corresponding to the amount of repetitions to volitional fatigue (below)

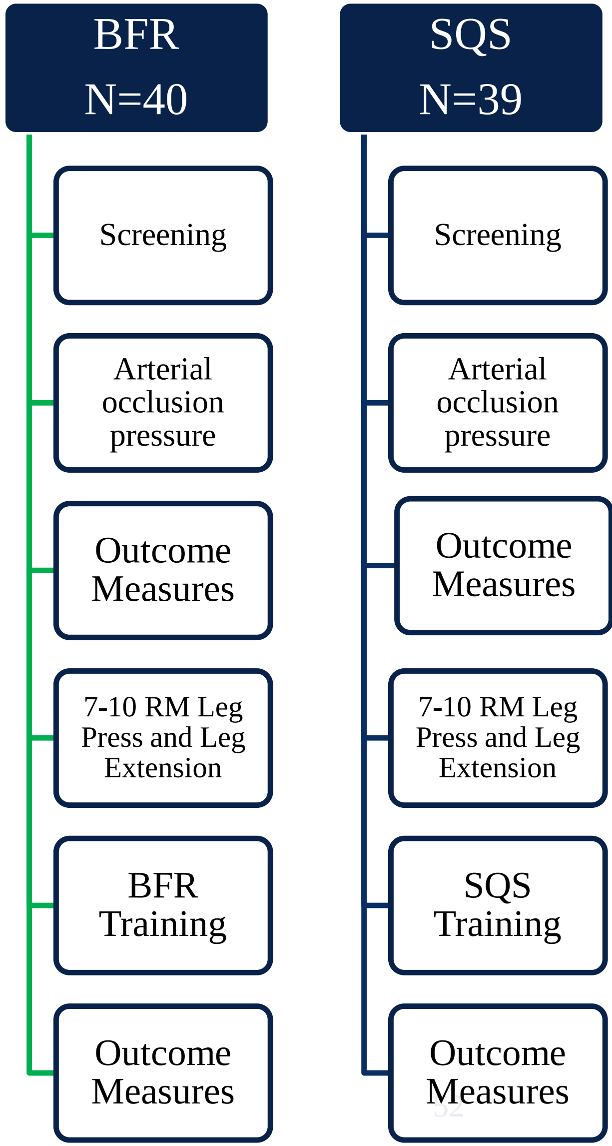
Leg press

Reps	7	8	9	10/10+
	x0.35	x0.36	x0.37	x0.38

Leg extension

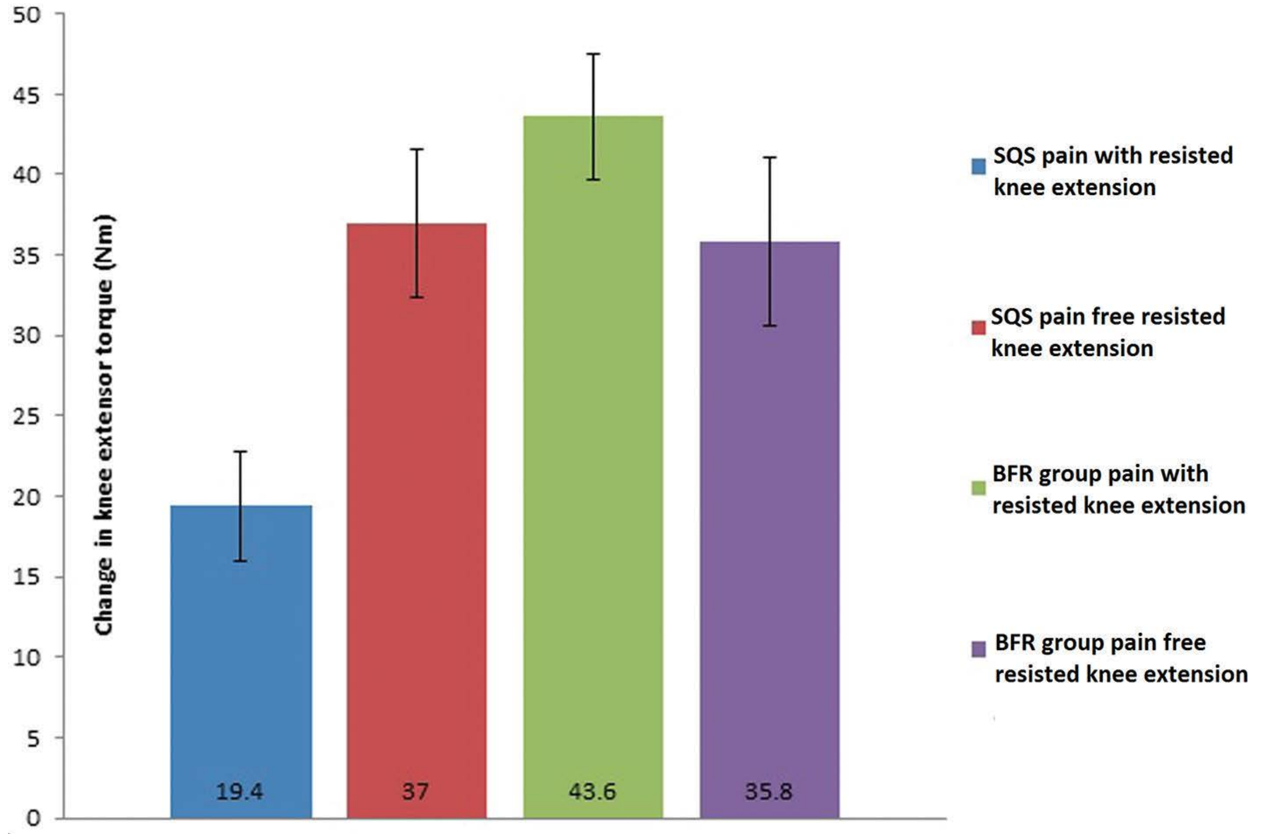
Reps	7	8	9	10/10+
	x0.37	x0.38	x0.38	x0.39

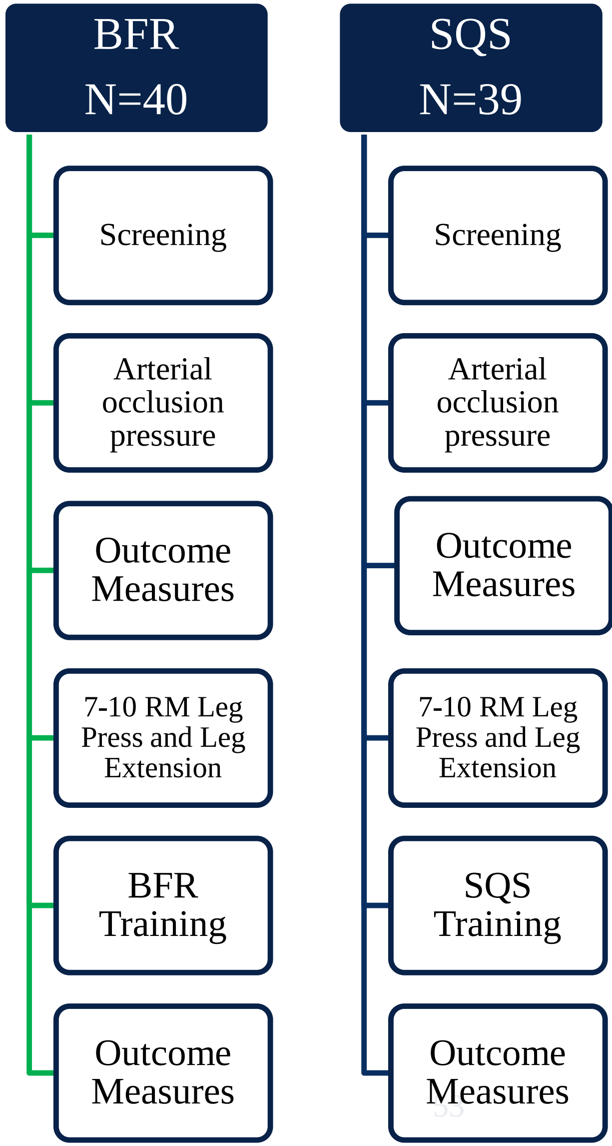
- **BFR Training**
  - Exercise at 30% 1RM with cuff inflated
  - 1 set of 30 reps (or fatigue) then 3 sets of 15 with 30 sec rest
- **Standardized Quad Strengthening**
  - 3 sets of 7-10 reps (70% 1RM) with placebo BFR on thigh



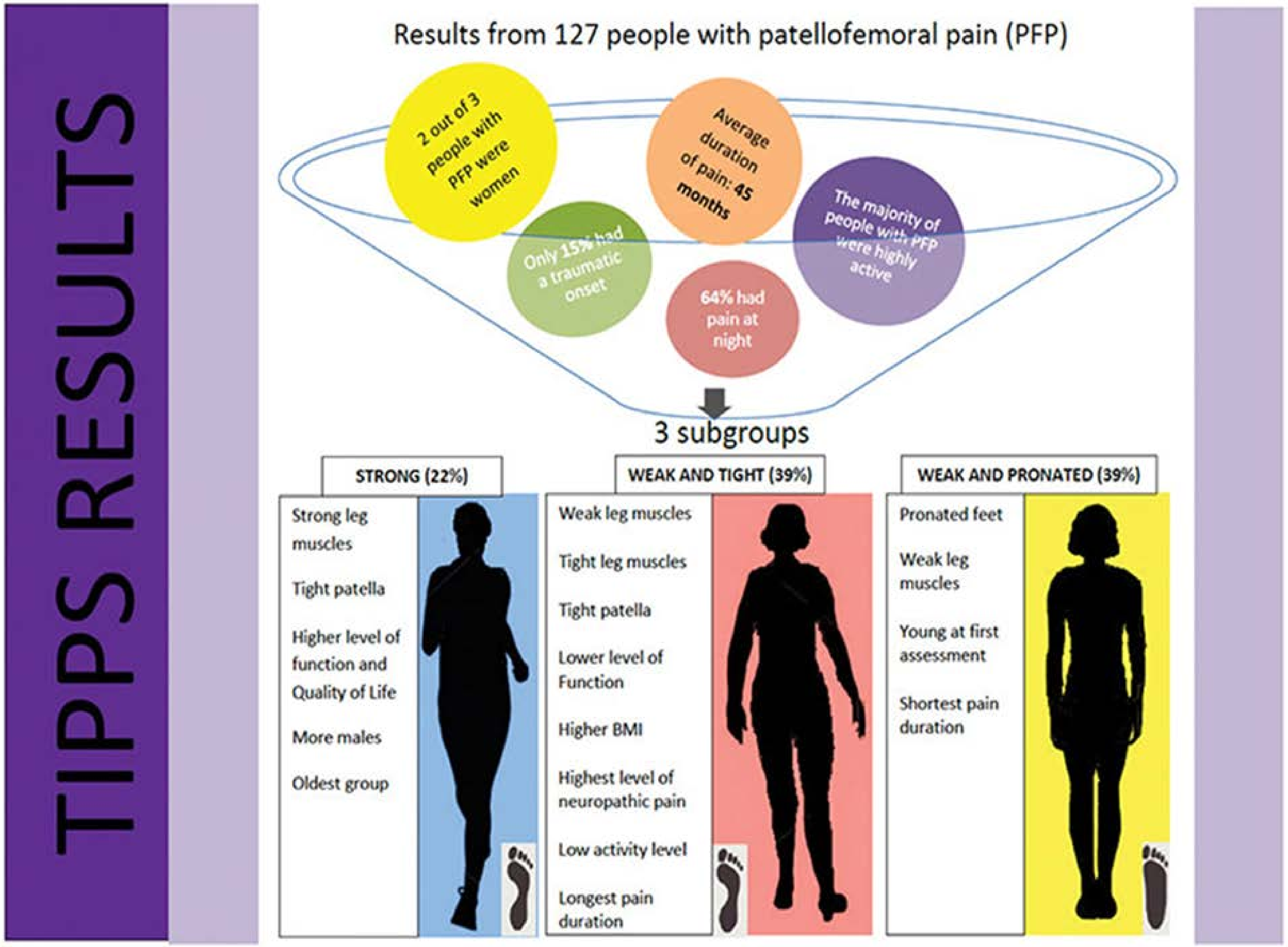
Blood Flow Restriction - Results

- **W-VAS, AKPS, pain with ADL and knee extensor torque improved in both groups**





Treating the Individual



Take Home Points

- Patients may not respond to traditional rehabilitation
- Neurological adaptations may impede recovery
- Think outside the box
- Individualize treatment

Thank You

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