TWIN CITIES ORTHOPEDICS

TRAINING HAUS
POWERED BY TCO

Quadriceps Activation Failure

Strategies for Restoration of Knee Performance

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TCO – Edina
December 7, 2021

Disclosures

- No conflicts of interest
- No disclosures

With Immense Gratitude

"If I have seen further, it is by standing on the shoulders of Giants."

- Isaac Newton, 1675

“I’m going to make you an offer you can’t refuse…”

AKA:
I’m going to make some suggestions you may want to consider…

1. Understand central & peripheral mechanisms of Arthrogenic Muscle Inhibition (AMI) following knee injury and/or surgery

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2. Apply interventional strategies to help facilitate early recovery of quadriceps activation

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2. Apply interventional strategies to help facilitate early recovery of quadriceps activation

3. **Create a theoretical framework for ultimate restoration of quadriceps capacity, including:**

    1. corticomotor function
    2. morphology
    3. maximum strength
    4. rate of force development

Specific Knee Diagnoses

Physical Therapy Interventions

Miscellaneous

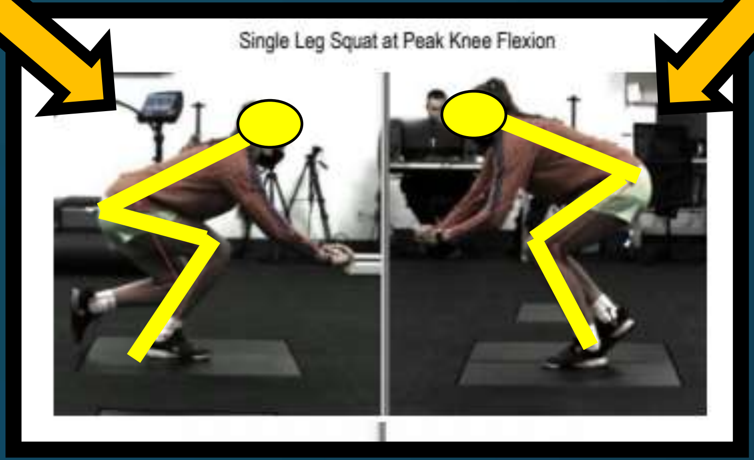
Physical Therapy Interventions

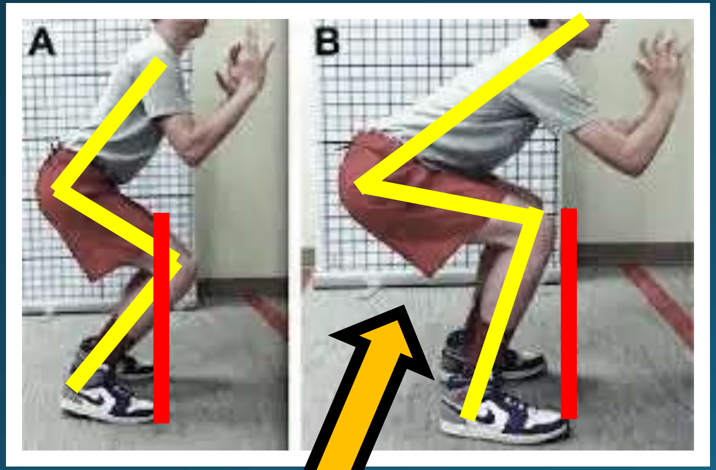
Specific Knee Diagnoses

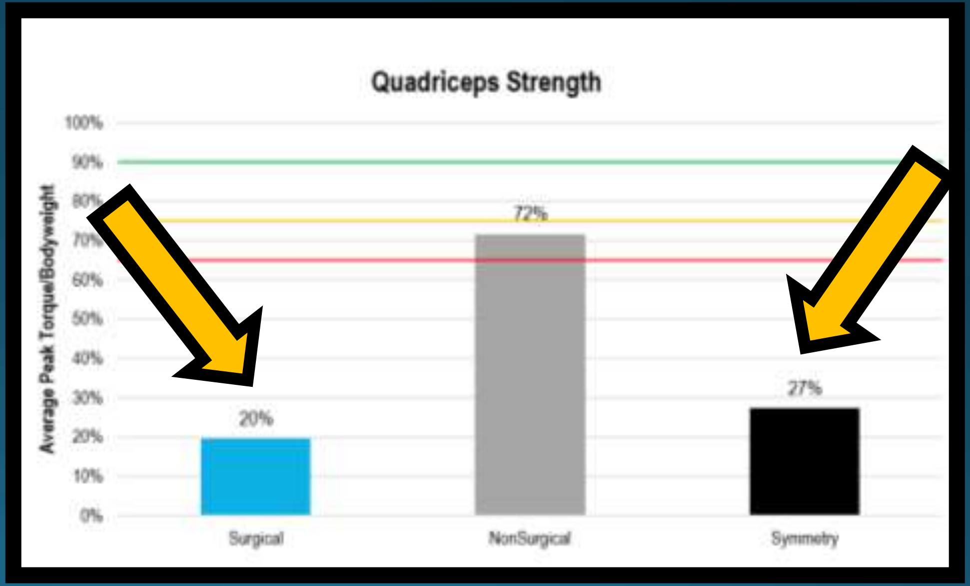
Physical Therapy Interventions

Miscellaneous

- Did I exit the womb with a beard?
- Am I privy to the catheter fortune?


Single Leg Squat at Peak Knee Flexion


A
B


Quadriceps Strength
Average Peak Torque/Bodyweight
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
20%
72%
27%
Surgical
NonSurgical
Symmetry

Review

Knee extensor muscle weakness is a risk factor for development of knee osteoarthritis. A systematic review and meta-analysis

B.E. Øiestad †*, C.B. Juhl ‡§, I. Eitzen ‖, J.B. Thorlund ‡

Voluntary Quadriceps Activation Deficits in Patients with Tibiofemoral Osteoarthritis: A Meta-Analysis

Brian G. Pietrosimone, PhD, ATC, Jay Hertel, PhD, ATC, FACSM, FNATA, Christopher D. Ingersoll, PhD, ATC, FACSM, FNATA, Joseph M. Hart, PhD, ATC, Susan A. Saliba, PhD, PT, ATC

Quadriceps Activation Failure as a Moderator of the Relationship Between Quadriceps Strength and Physical Function in Individuals With Knee Osteoarthritis

G. KELLEY FITZGERALD,[1] SARA R. PIVA,[1] JAMES J. IRRGANG,[1] FAWZI BOUZUBAR,[1] AND TERENCE W. STARZ[2]

Impaired Isometric, Concentric, and Eccentric Rate of Torque Development at the Hip and Knee in Patellofemoral Pain

Amanda S. Ferreira,[1] Danilo de Oliveira Silva,[1,2] Christian J. Barton,[2] Ronaldo V. Briani,[1] Bianca Taborda,[1] Marcella F. Pazzinatto,[1,2] and Fábio M. de Azevedo[1]

Quadriceps strength and volitional activation before and after total knee arthroplasty for osteoarthritis

Jennifer E. Stevens [a,b], Ryan L. Mizner [a], Lynn Snyder-Mackler [a,*]

Quadriceps Activation Following Knee Injuries: A Systematic Review

Joseph M. Hart, PhD, ATC; Brian Pietrosimone, PhD, ATC; Jay Hertel, PhD, ATC, FNATA, FACSM; Christopher D. Ingersoll, PhD, ATC, FNATA, FACSM

Arthritis Care & Research
Vol. 67, No. 9, September 2015, pp 1289–1296
DOI 10.1002/acr.22581

ORIGINAL ARTICLE

Knee Extensor Muscle Strength in Middle-Aged and Older Individuals Undergoing Arthroscopic Partial Meniscectomy: A Systematic Review and Meta-Analysis

MICHELLE HALL,[1] CARSTEN B. JUHL,[2] HANS LUND,[3] AND JONAS B. THORLUND[4]

Quadriceps Strength and Volitional Activation After Anterior Cruciate Ligament Reconstruction: A Systematic Review and Meta-analysis

Caroline Lisee, MEd, ATC,*† Adam S. Lepley, PhD, ATC,‡§ Thomas Birchmeier, MS, ATC,† Kaitlin O'Hagan, MS,‖ and Christopher Kuenze, PhD, ATC†‖

Can Biomechanical Testing After Anterior Cruciate Ligament Reconstruction Identify Athletes at Risk for Subsequent ACL Injury to the Contralateral Uninjured Limb?

Enda King, Chris Richter, Katherine A J Daniels, Andy Franklyn-Miller, Eanna Falvey, Gregory D Myer, Mark Jackson, Ray Moran, Siobhan Strike

ELSEVIER
Clinical Biomechanics
Volume 17, Issue 1, January 2002, Pages 56-63

The effect of insufficient quadriceps strength on gait after anterior cruciate ligament reconstruction

Michael Lewek[a], Katherine Rudolph[a], Michael Axe[a, b], Lynn Snyder-Mackler[a]

CLINICAL SCIENCES

Quadriceps Strength Predicts Self-reported Function Post-ACL Reconstruction

PIETROSIMONE, BRIAN; LEPLEY, ADAM S.; HARKEY, MATTHEW S.; LUC-HARKEY, BRITTNEY A.; BLACKBURN, J. TROY; GRIBBLE, PHILLIP A.; SPANG, JEFFREY T.; SOHN, DAVID H.

Simple decision rules can reduce reinjury risk by 84% after ACL reconstruction: the Delaware-Oslo ACL cohort study

Hege Grindem,[1] Lynn Snyder-Mackler,[2] Håvard Moksnes,[3] Lars Engebretsen,[3,4] May Arna Risberg[1,4]

Poor functional performance 1 year after ACL reconstruction increases the risk of early osteoarthritis progression

Brooke Patterson,[1] Adam Geoffrey Culvenor,[1,2] Christian J Barton,[1] Ali Guermazi,[3] Joshua Stefanik,[4] Hayden G Morris,[5] Timothy S Whitehead,[6] Kay M Crossley[1]

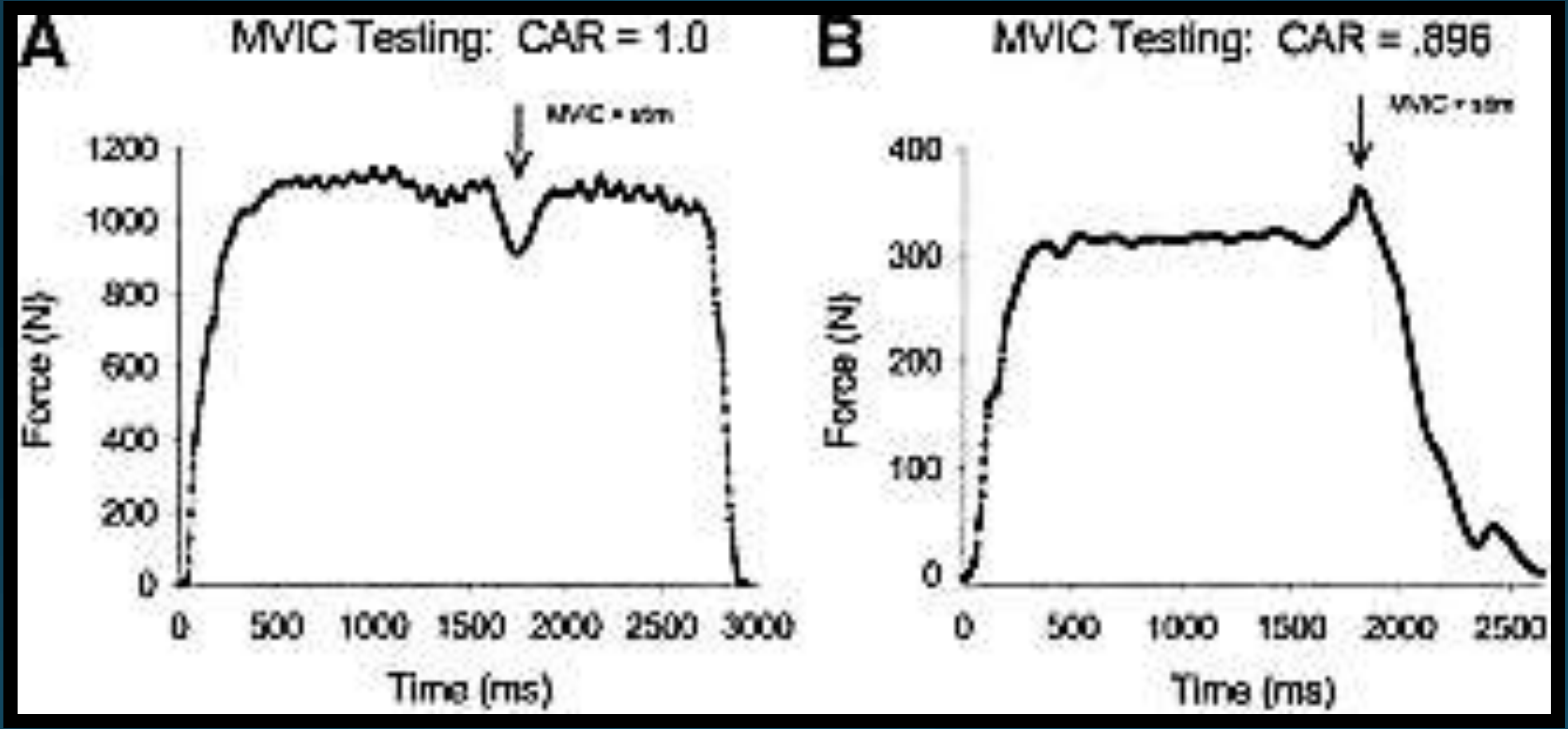
Scand J Med Sci Sports 2014: 24: e501–e509
doi: 10.1111/sms.12215

SCANDINAVIAN JOURNAL OF MEDICINE & SCIENCE IN SPORTS

Anterior cruciate ligament injury after more than 20 years. II. Concentric and eccentric knee muscle strength

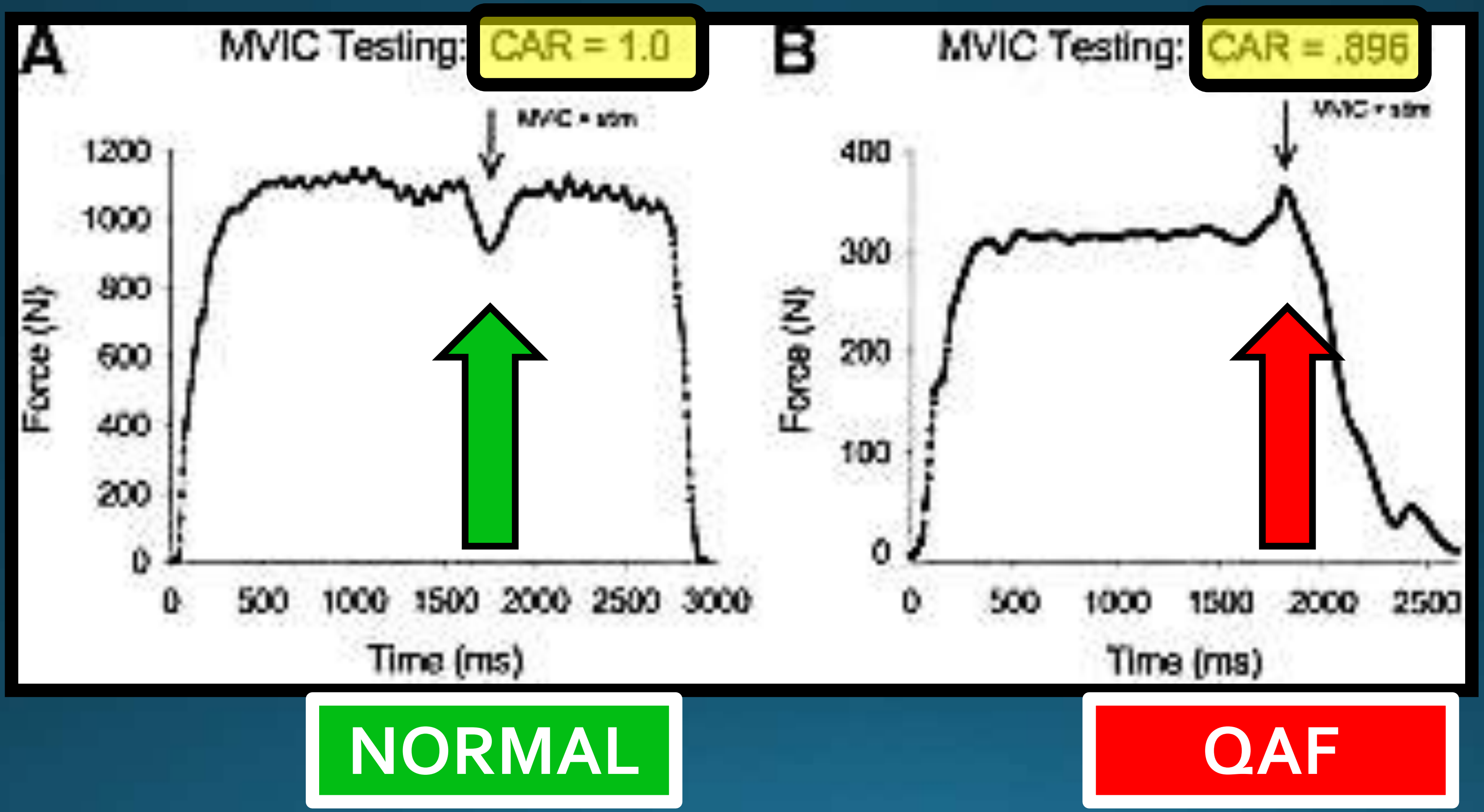
E. Tengman[1], L. Brax Olofsson[2], A. K. Stensdotter[1,3], K. G. Nilsson[2], C. K. Häger[1]

"Quadriceps Activation Failure"



Stevens JE, Binder-Macleod S, Snyder-Mackler L. Characterization of the human quadriceps muscle in active elders. Arch Phys Med Rehabil 2001;82:973-8.

"Quadriceps Activation Failure"



Stevens JE, Binder-Macleod S, Snyder-Mackler L. Characterization of the human quadriceps muscle in active elders. Arch Phys Med Rehabil 2001;82:973-8.

Journal of Athletic Training 2010;45(1):87–97
www.nata.org/jat

systematic review

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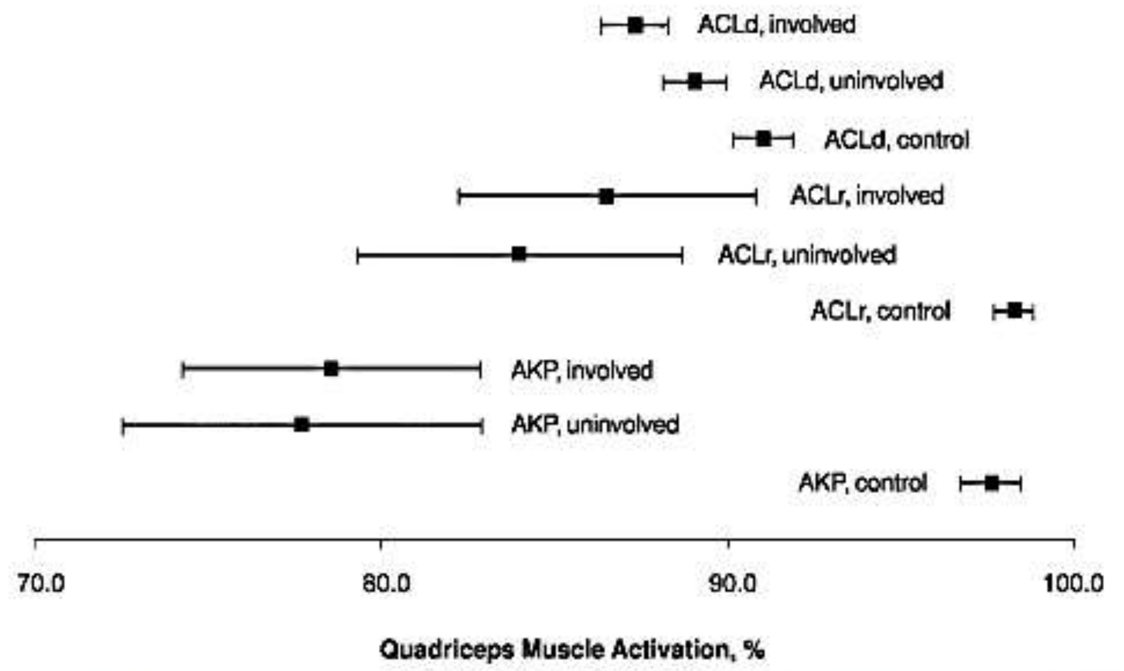

Figure 3. Average quadriceps activation data for the involved, uninvolved, and control limbs in all studies included in this review. Data points represent weighted averages, and error bars represent 95% confidence intervals. Abbreviations: ACLd, anterior cruciate ligament deficiency; ACLr, anterior cruciate ligament reconstruction; AKP, anterior knee pain.

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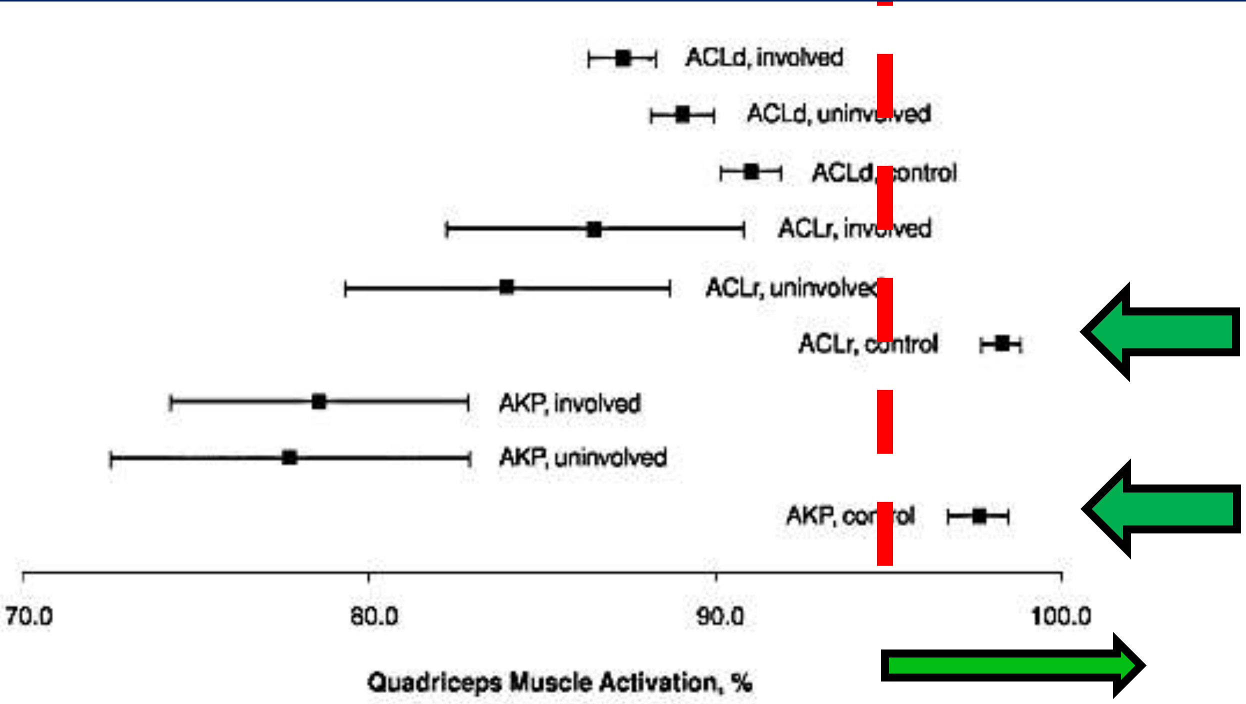

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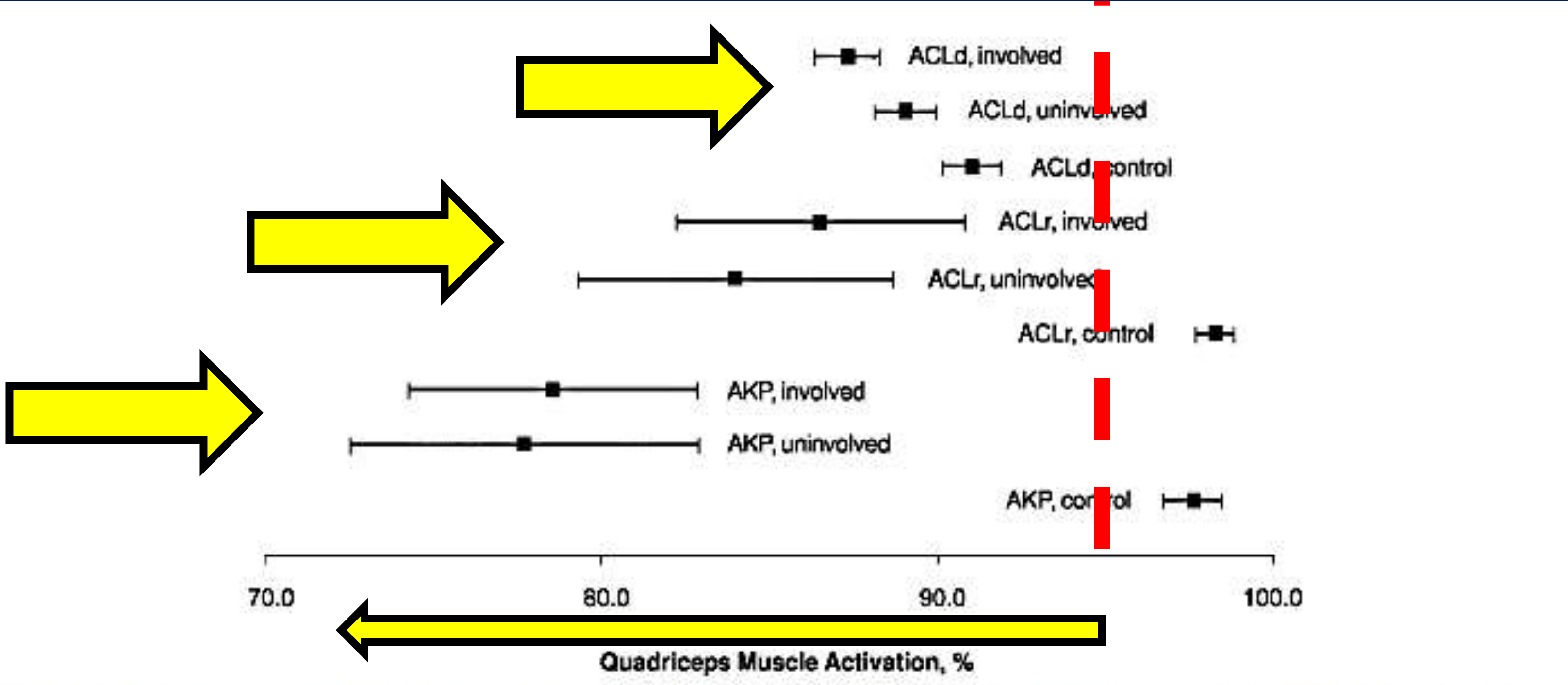

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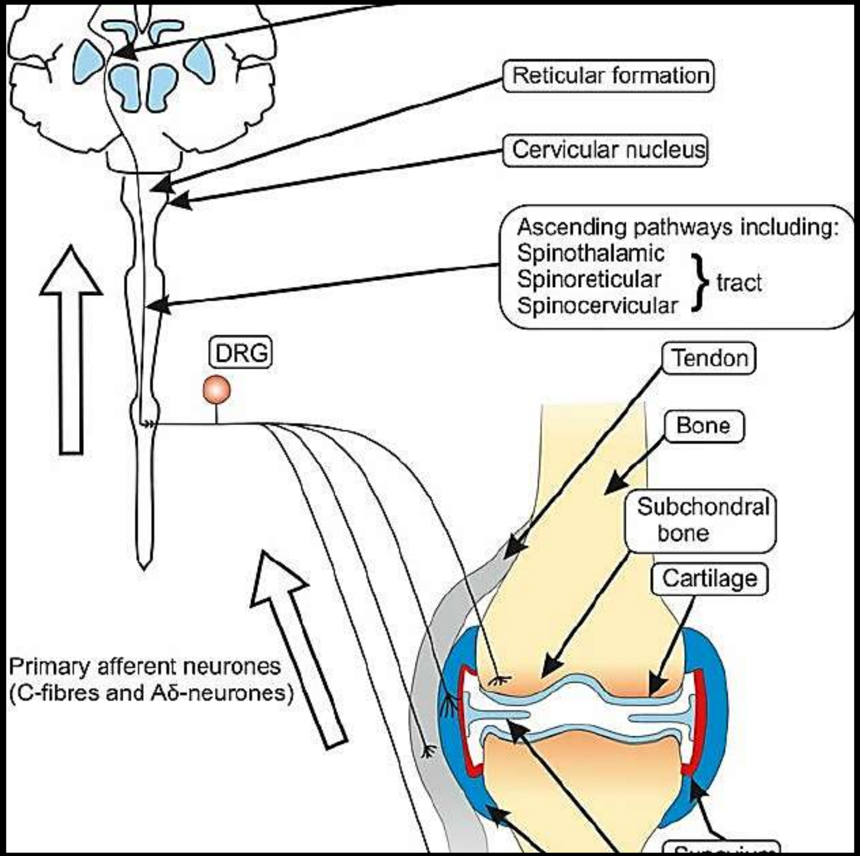
TWIN CITIES ORTHOPEDICS

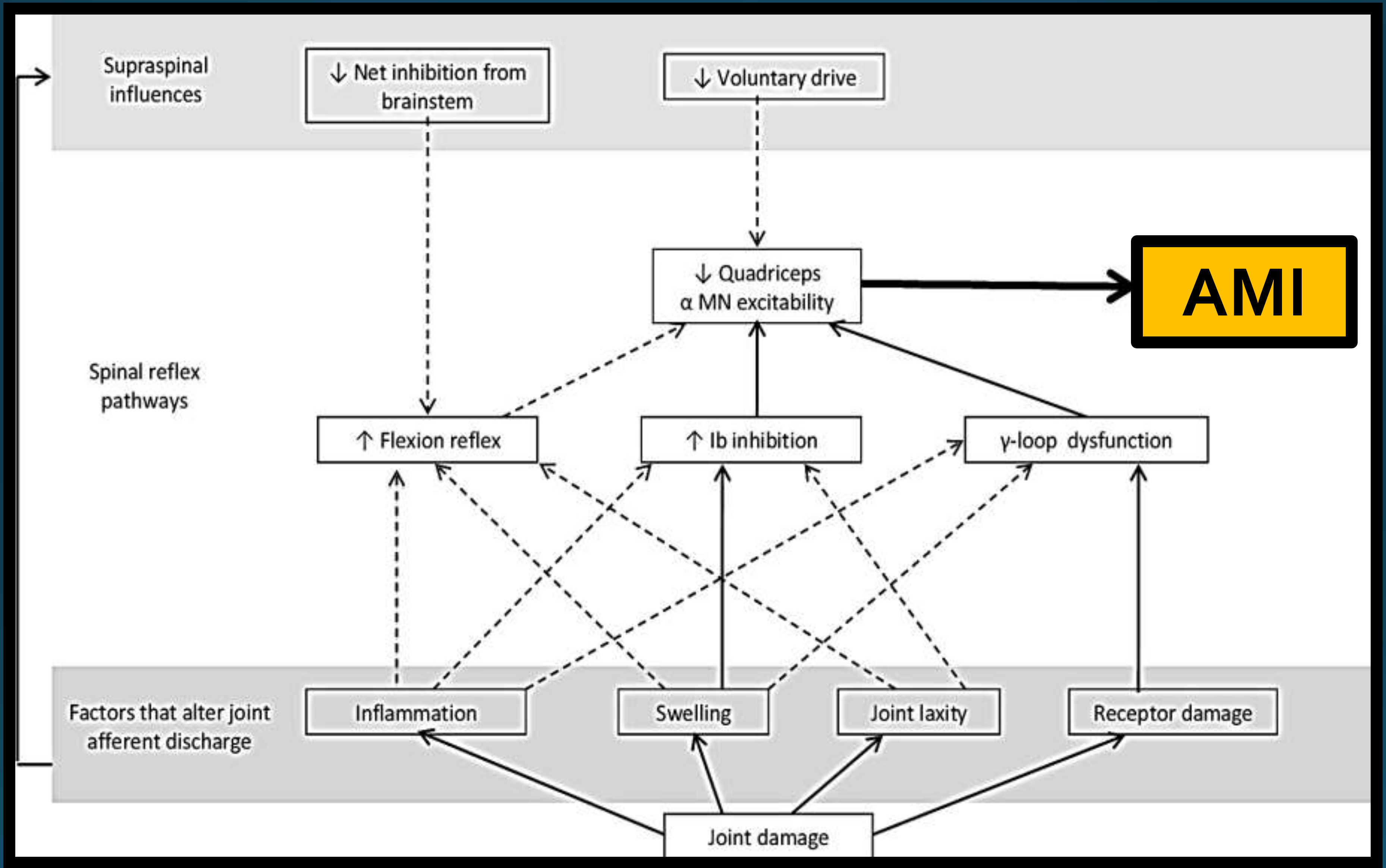
TRAINING HAUS

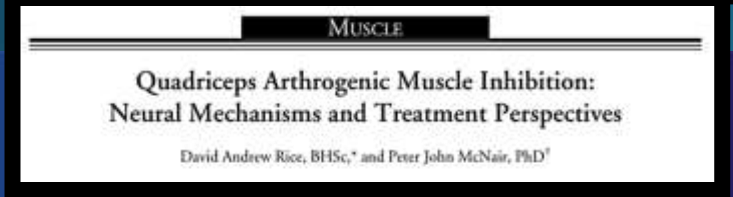
MUSCLE

Quadriceps Arthrogenic Muscle Inhibition: Neural Mechanisms and Treatment Perspectives

David Andrew Rice, BHSc,* and Peter John McNair, PhD†






MUSCLE

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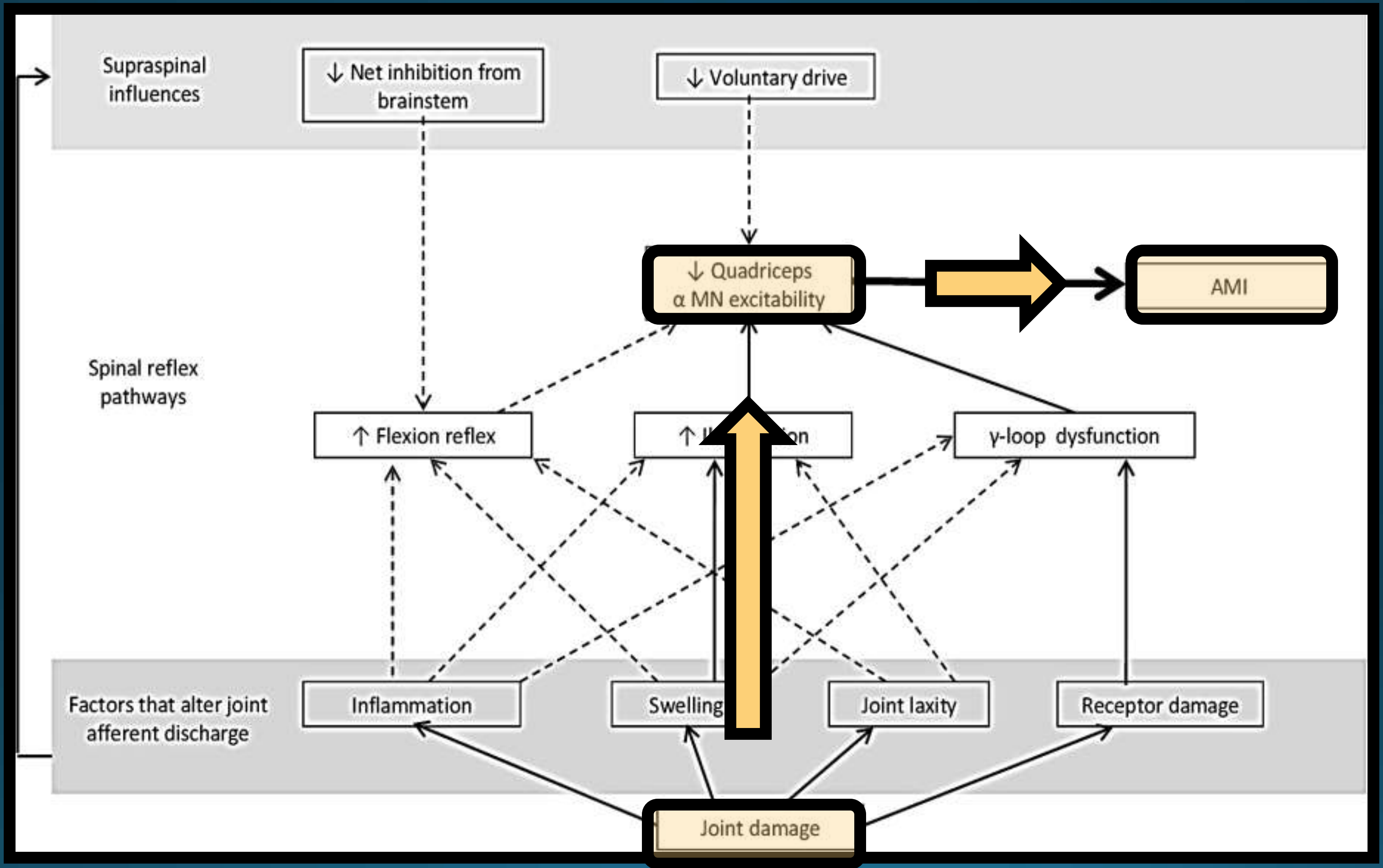
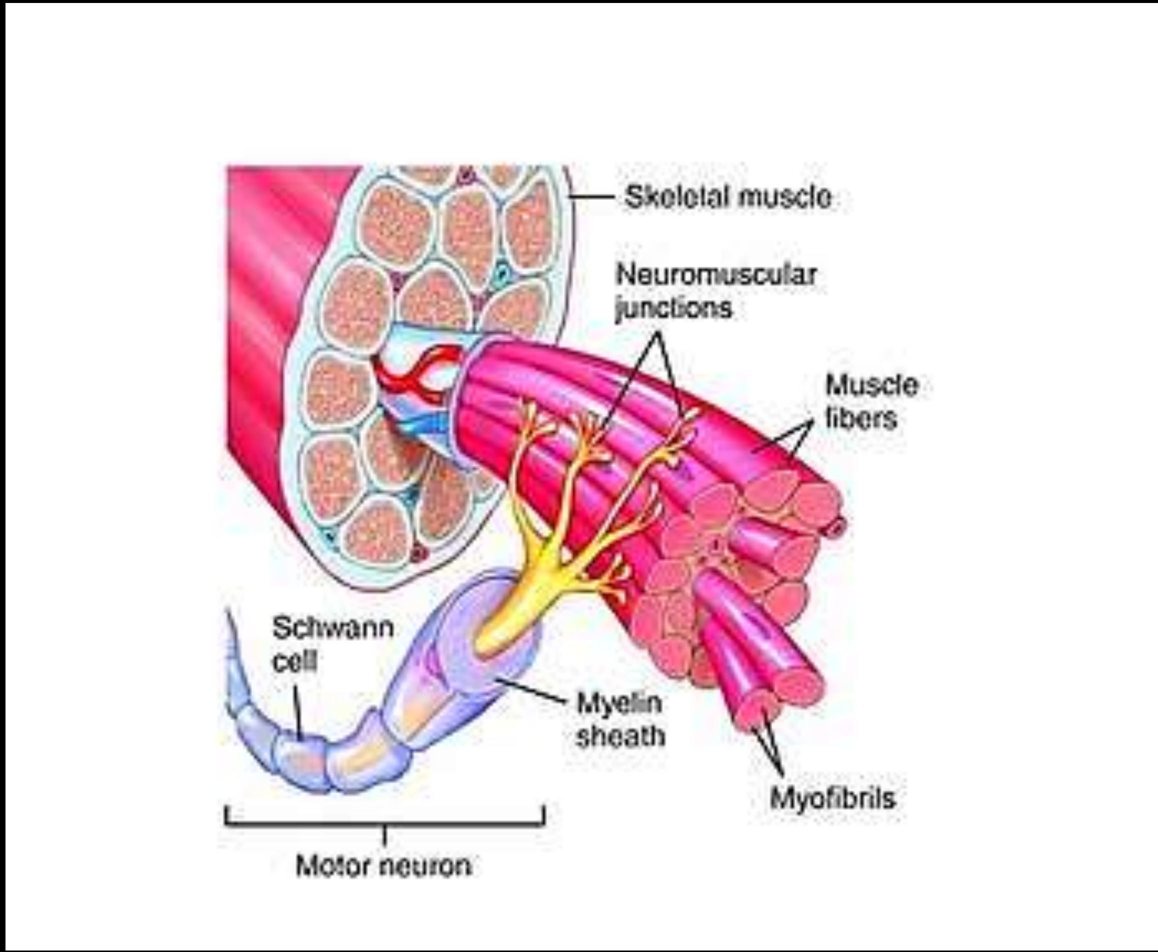
David Andrew Rice, BHSc,[*] and Peter John McNair, PhD[†]

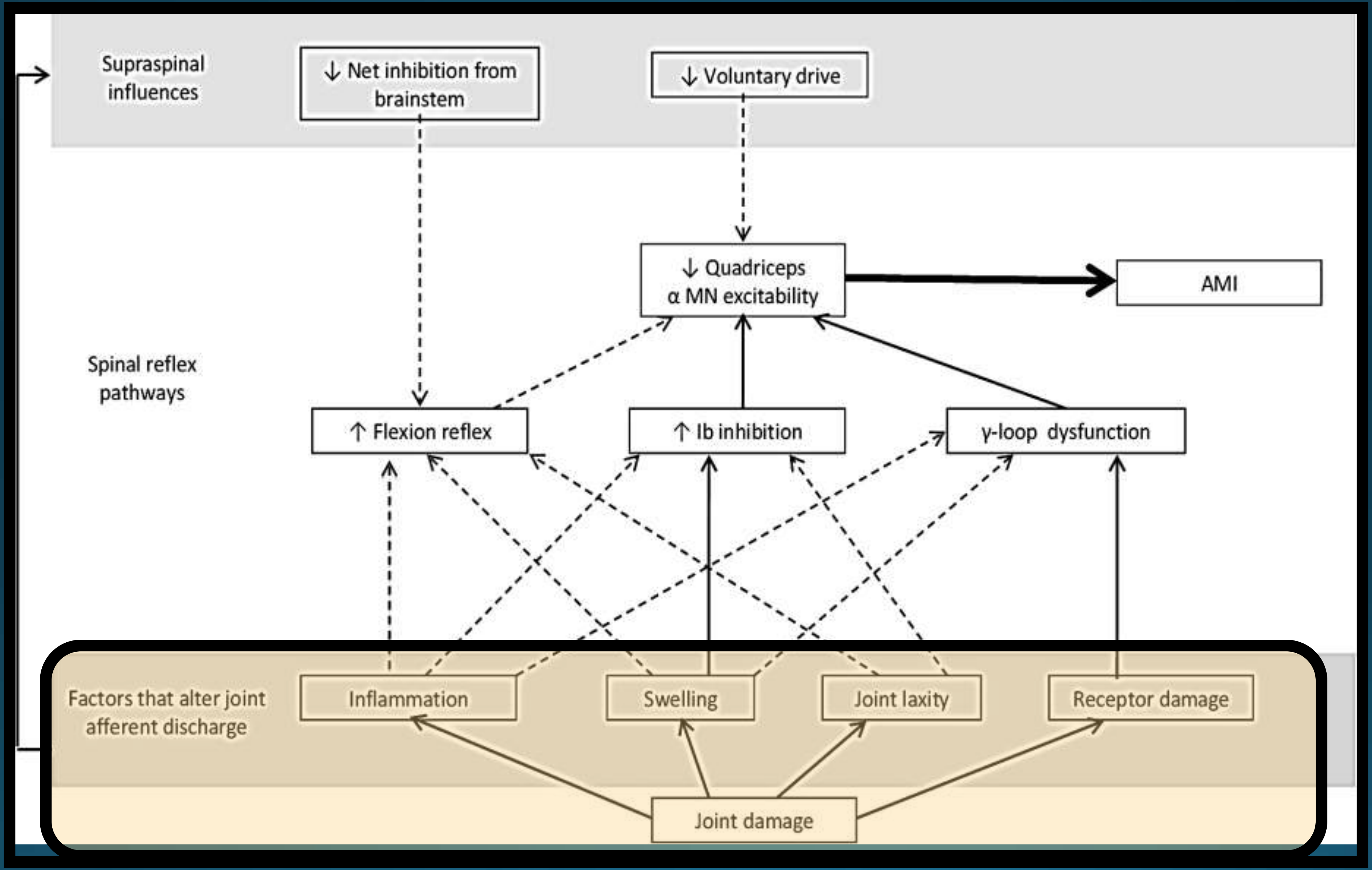
TWIN CITIES ORTHOPEDICS | TRAINING HAUS


Supraspinal influences
↓ Net inhibition from brainstem
↓ Voluntary drive
↓ Quadriceps α MN excitability
AMI
Spinal reflex pathways
↑ Flexion reflex
γ-loop dysfunction
Factors that alter joint afferent discharge
Inflammation
Swelling
Joint laxity
Receptor damage
Joint damage

A(n incredibly rapid) refresher…



https://en.wikipedia.org/wiki/Motor_pool_(neuroscience)#/media/File:Anatomical_diagram_of_the_motor_unit.jpg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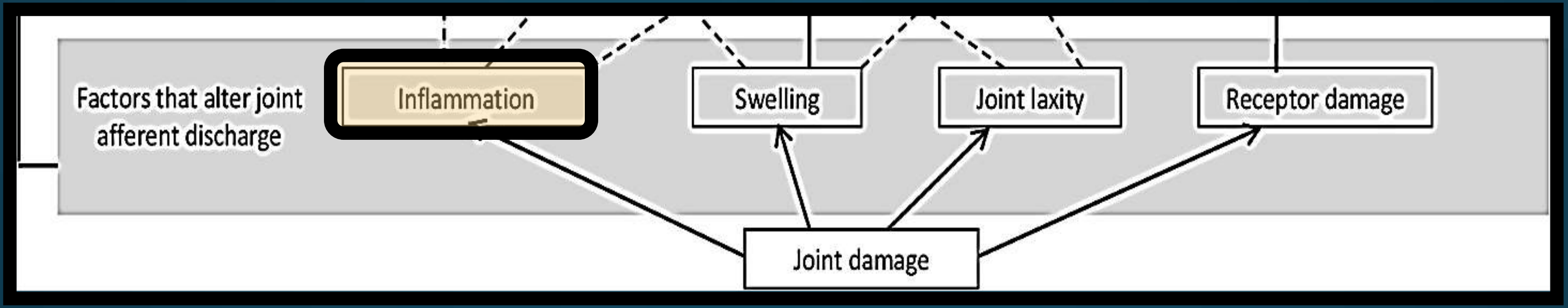
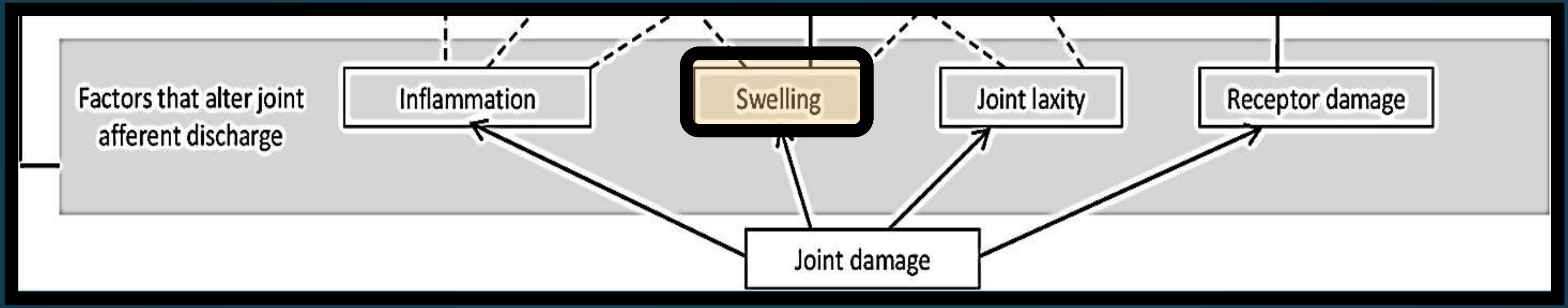
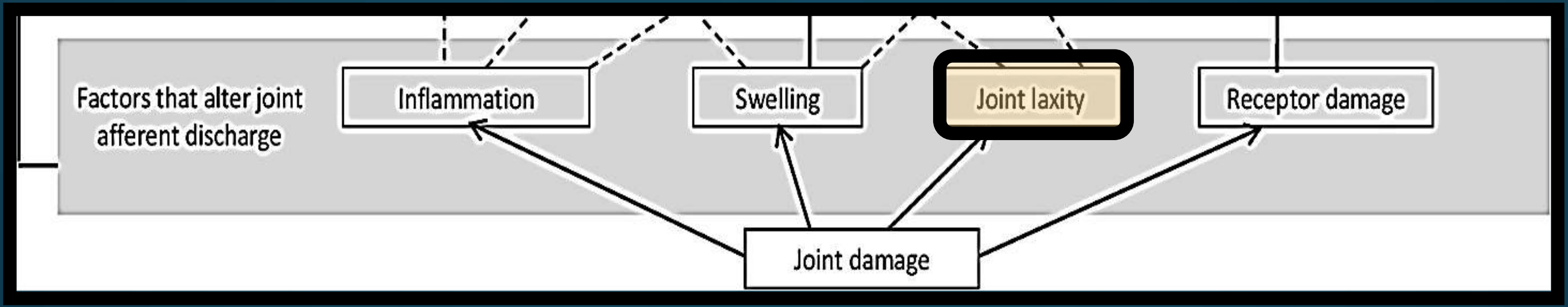


Inflammation/Pain

Maybe –
magnitude unknown

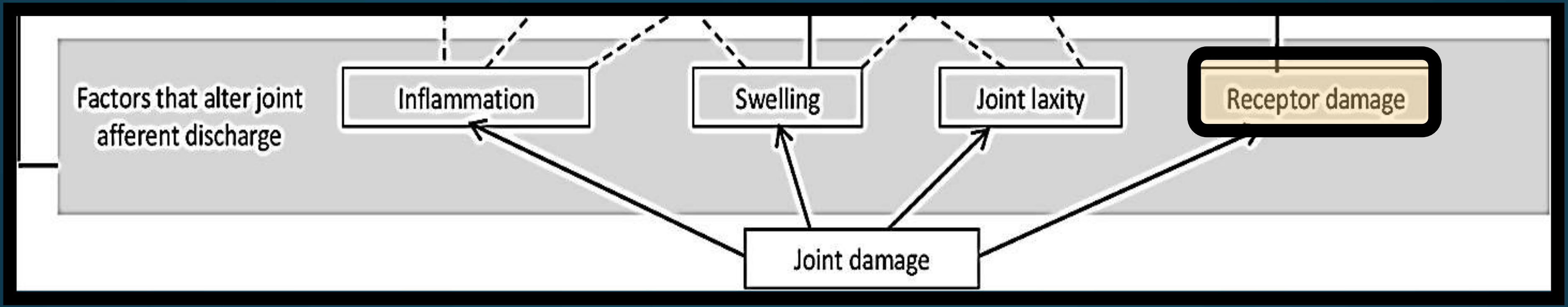


Effusion = ↓ Force output



Joint laxity

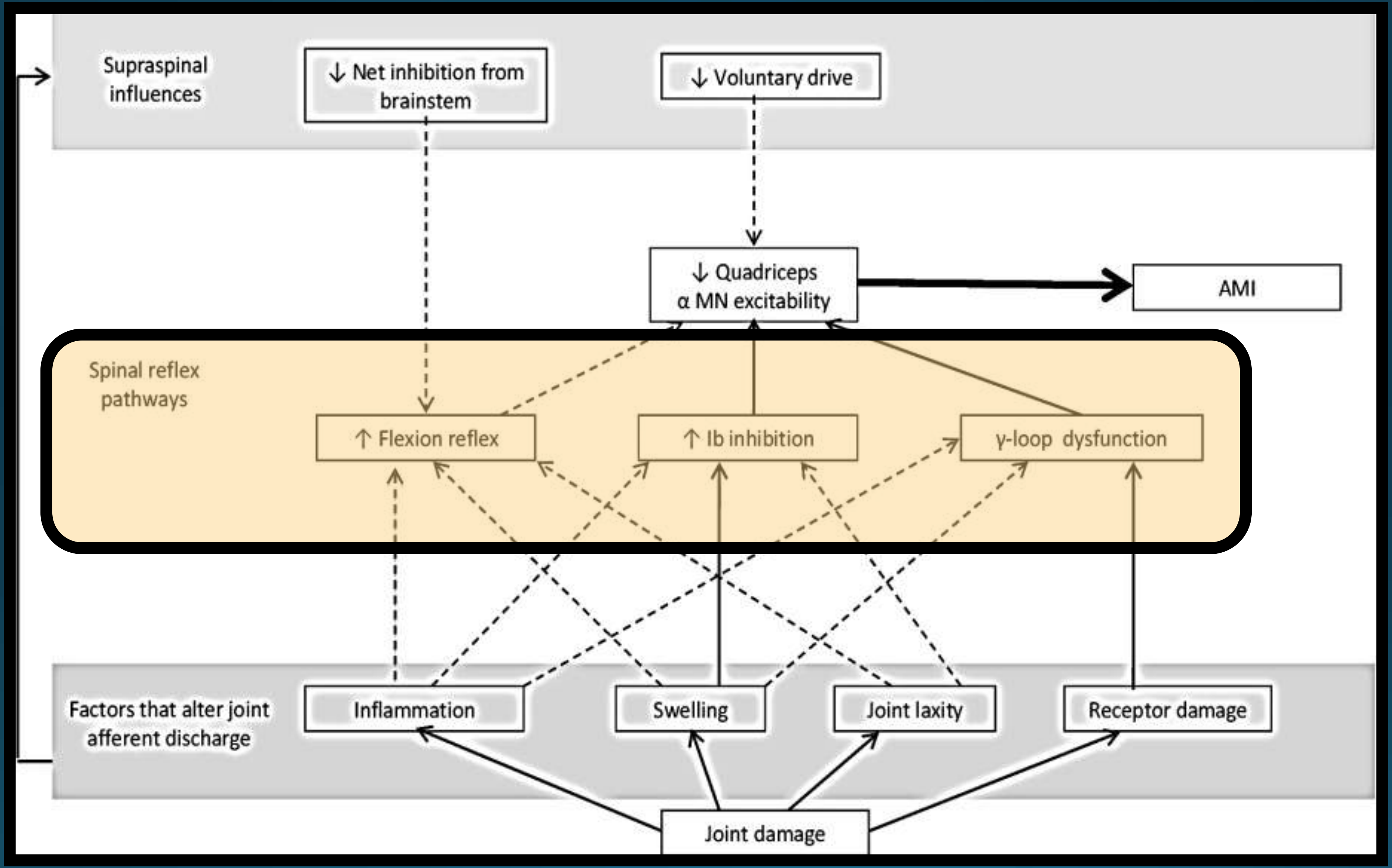
Abnormal afferent:
9-18 months



Damage to Articular Receptors

…maybe…

https://radiopaedia.org/articles/osteoarthritis-of-the-knee?lang=us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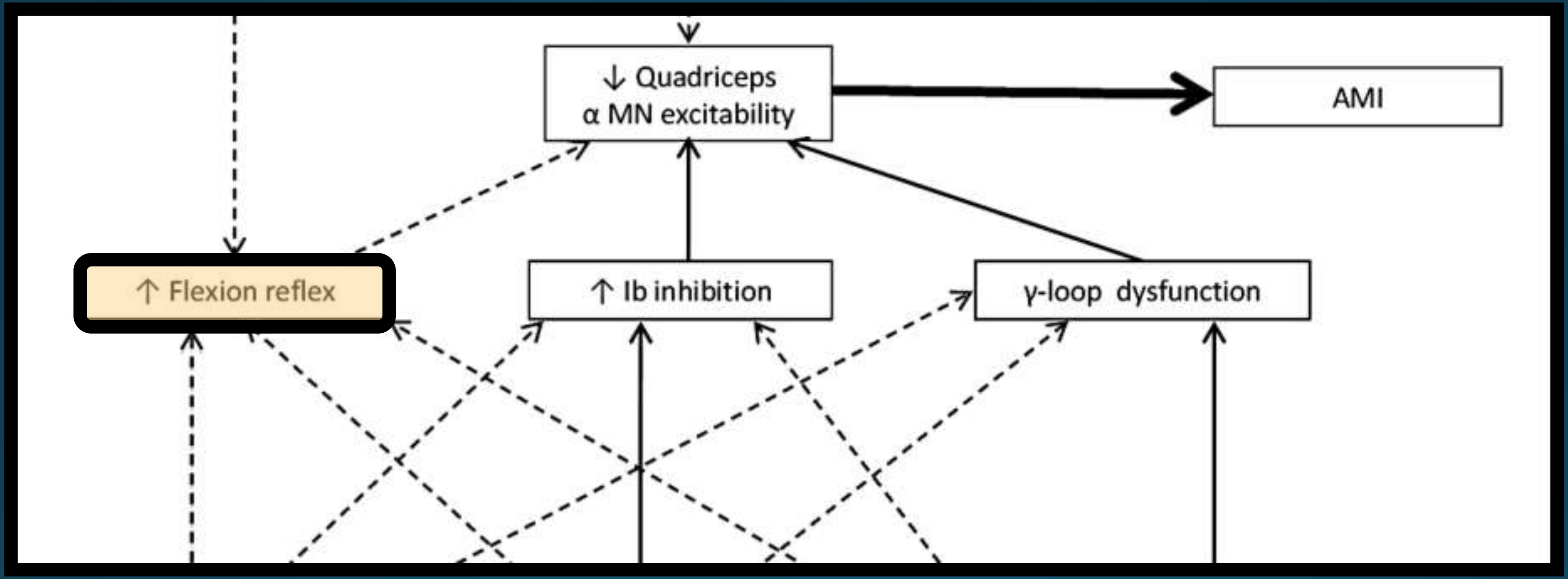
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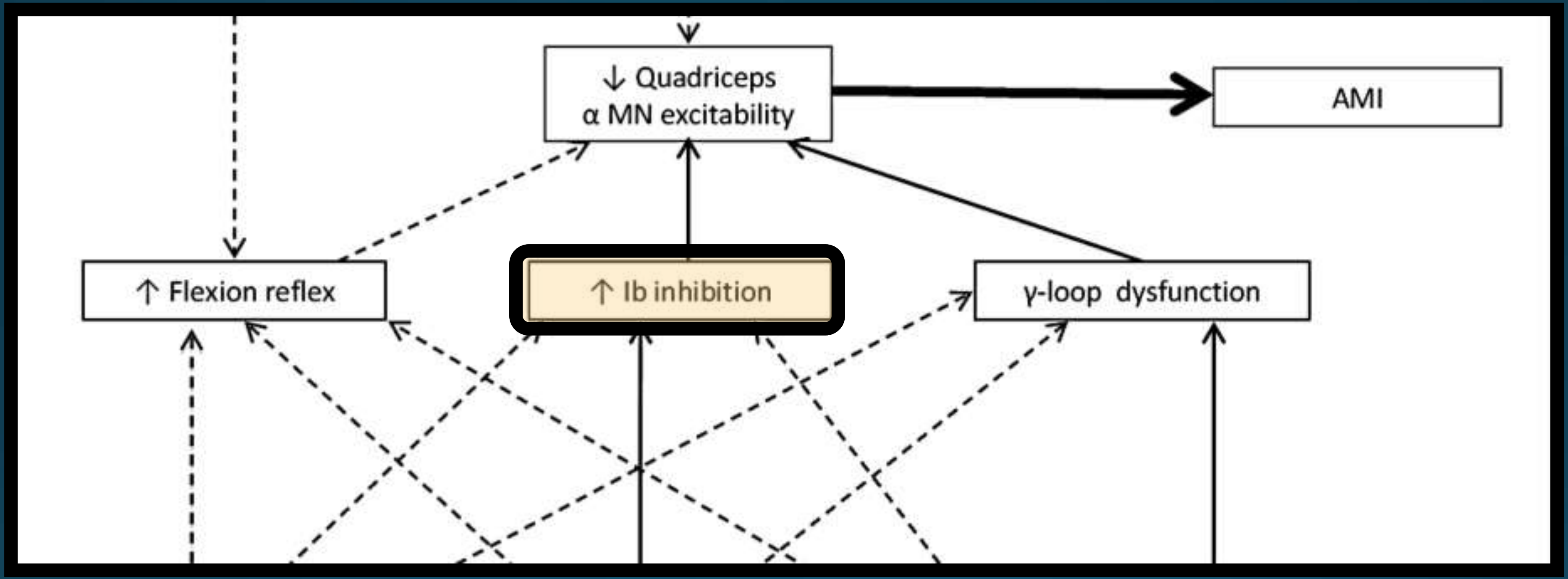
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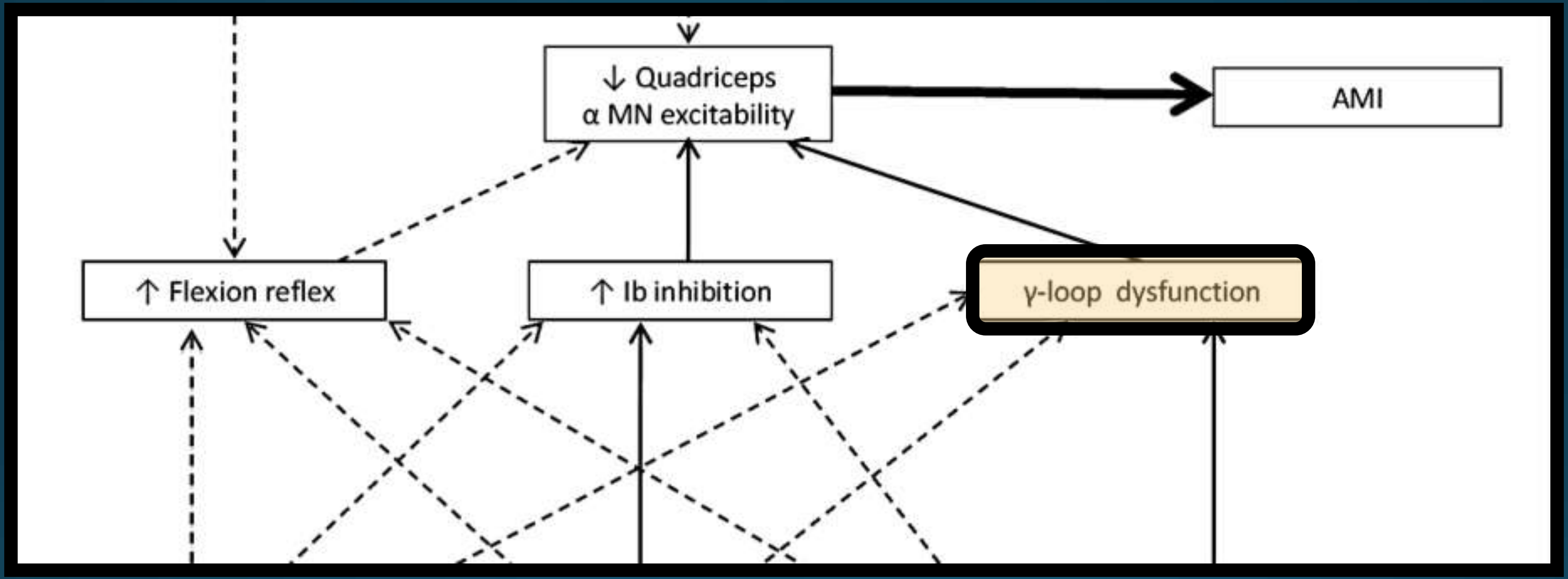
γ-loop dysfunction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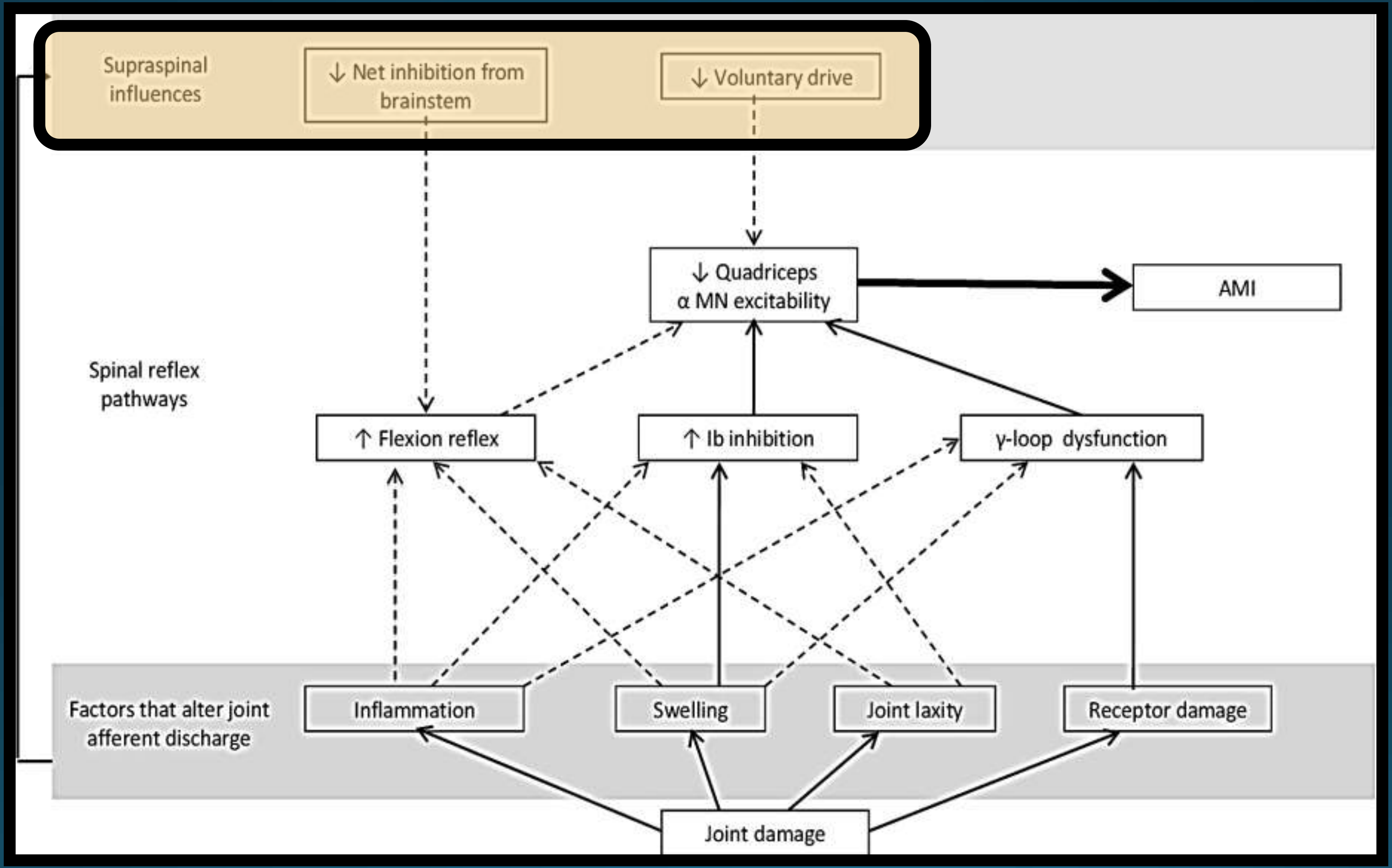
γ-loop dysfunction



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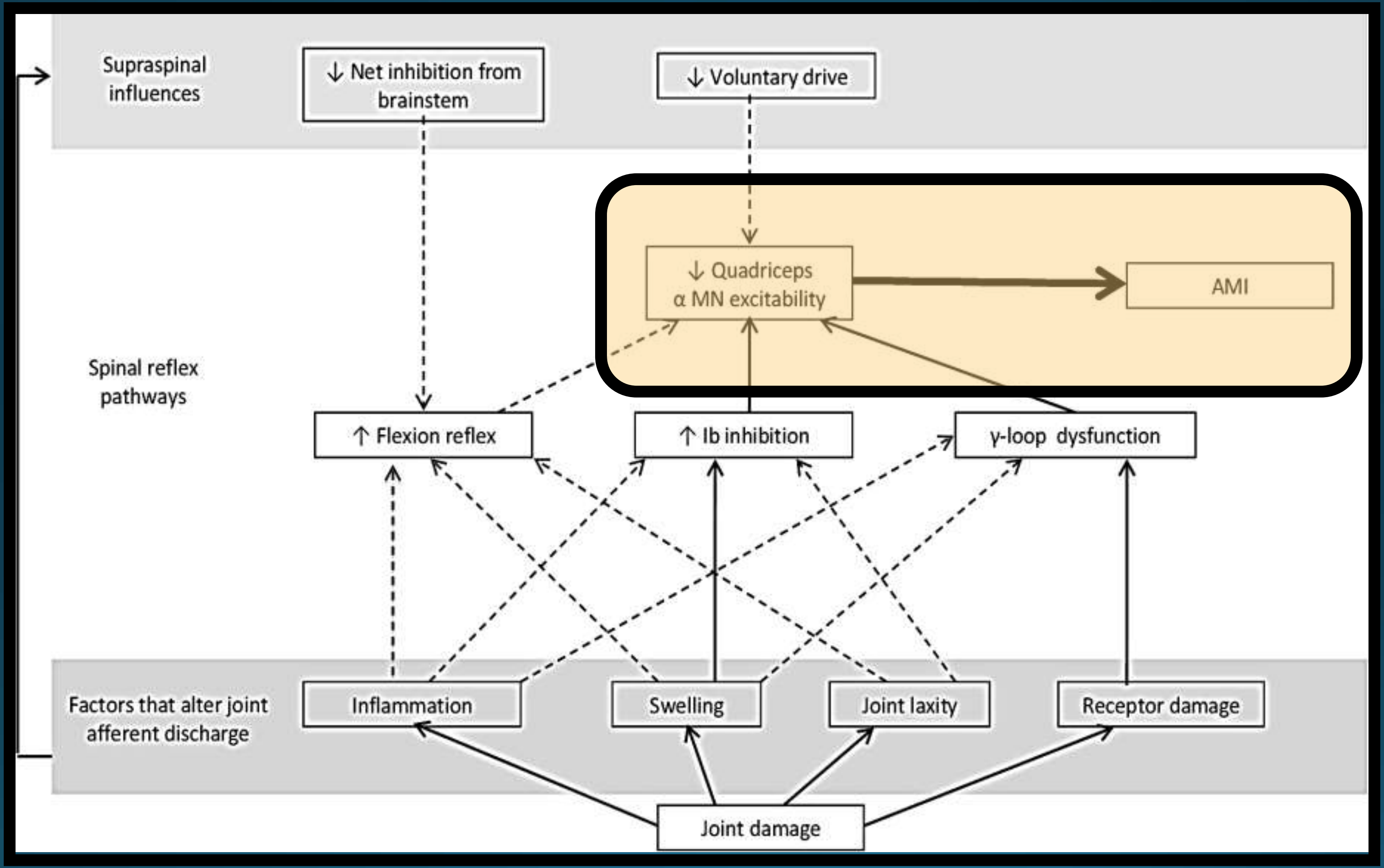
Receptor damage
Joint damage



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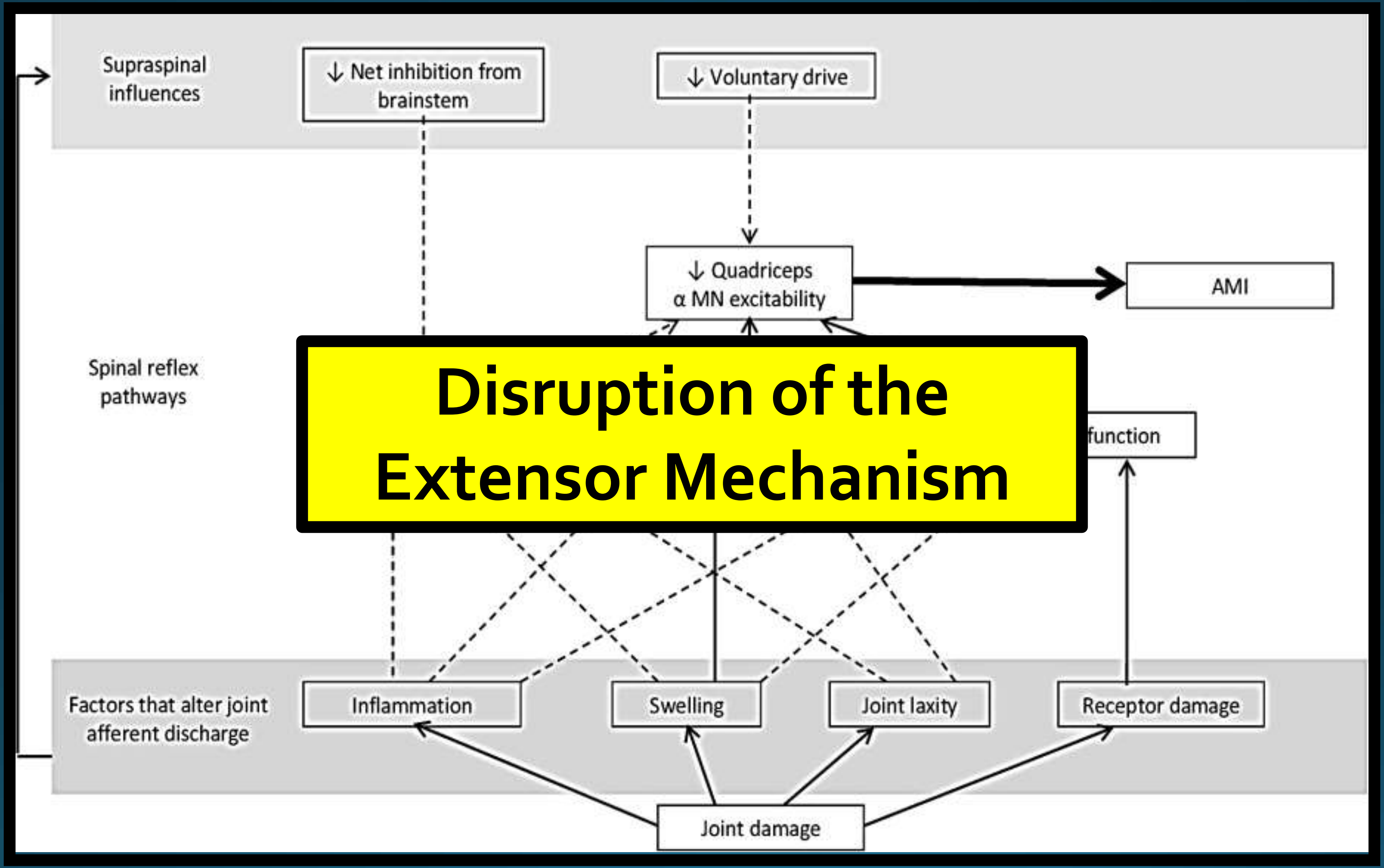
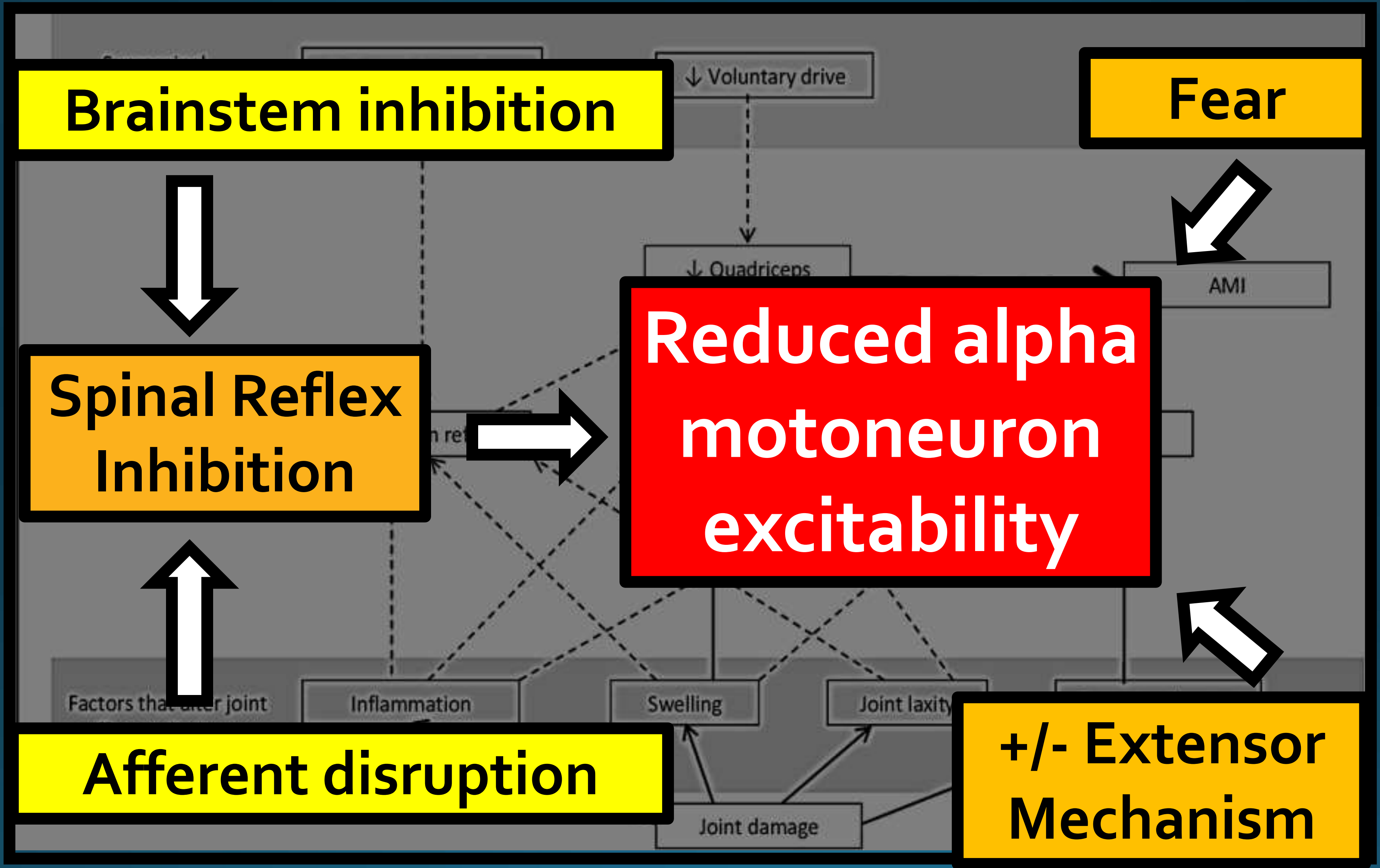
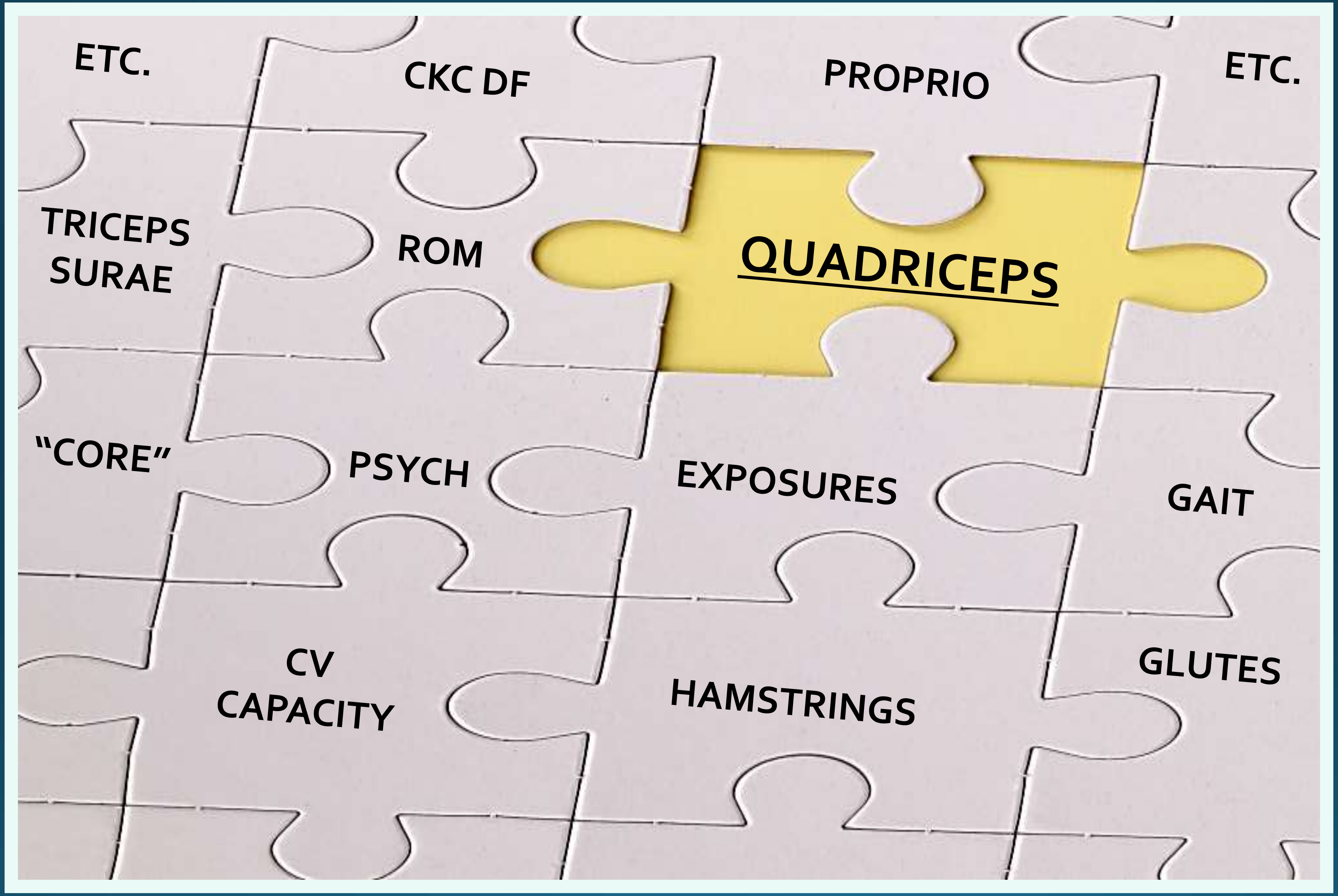
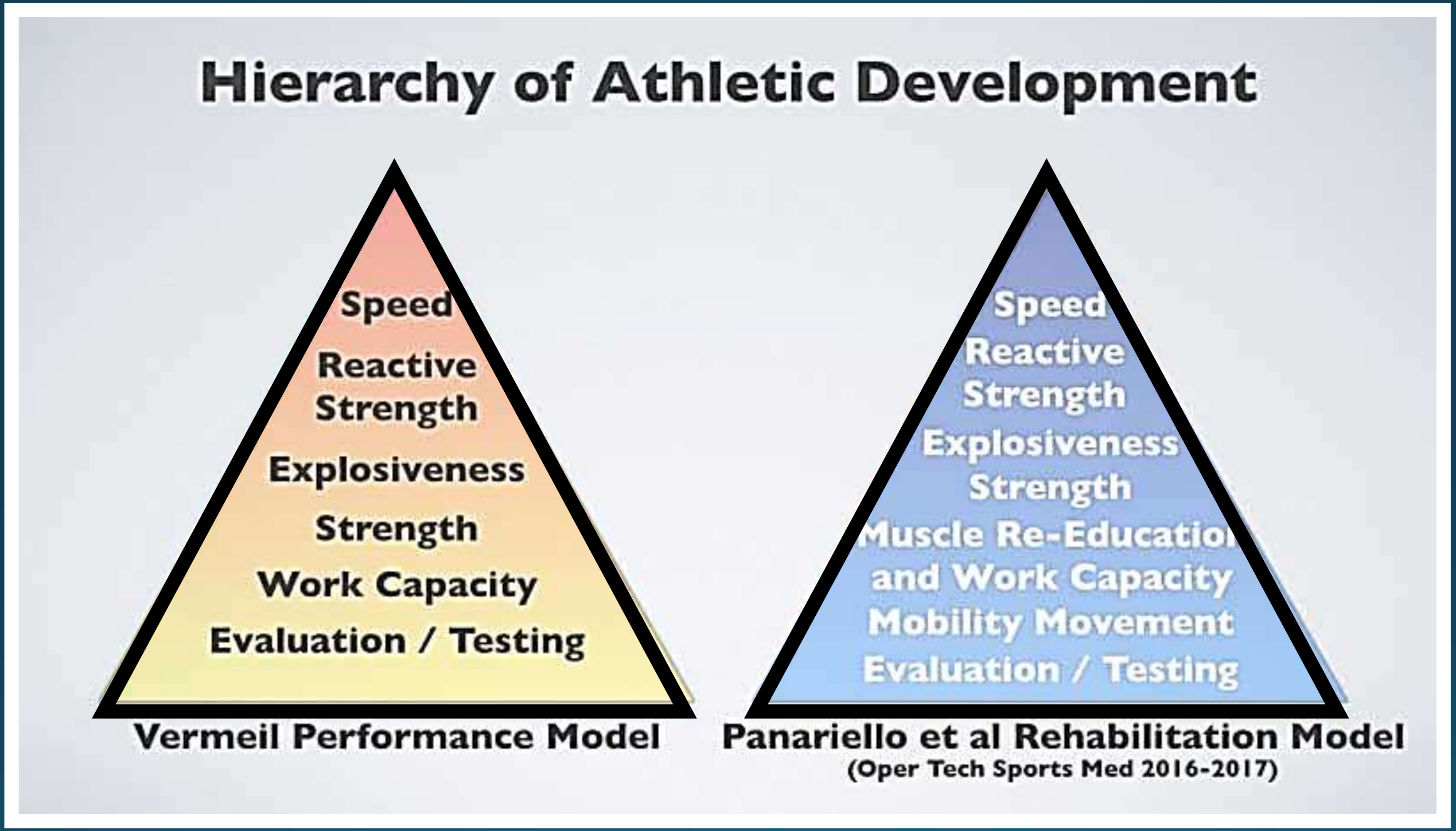


Disruption of the Extensor Mechanism

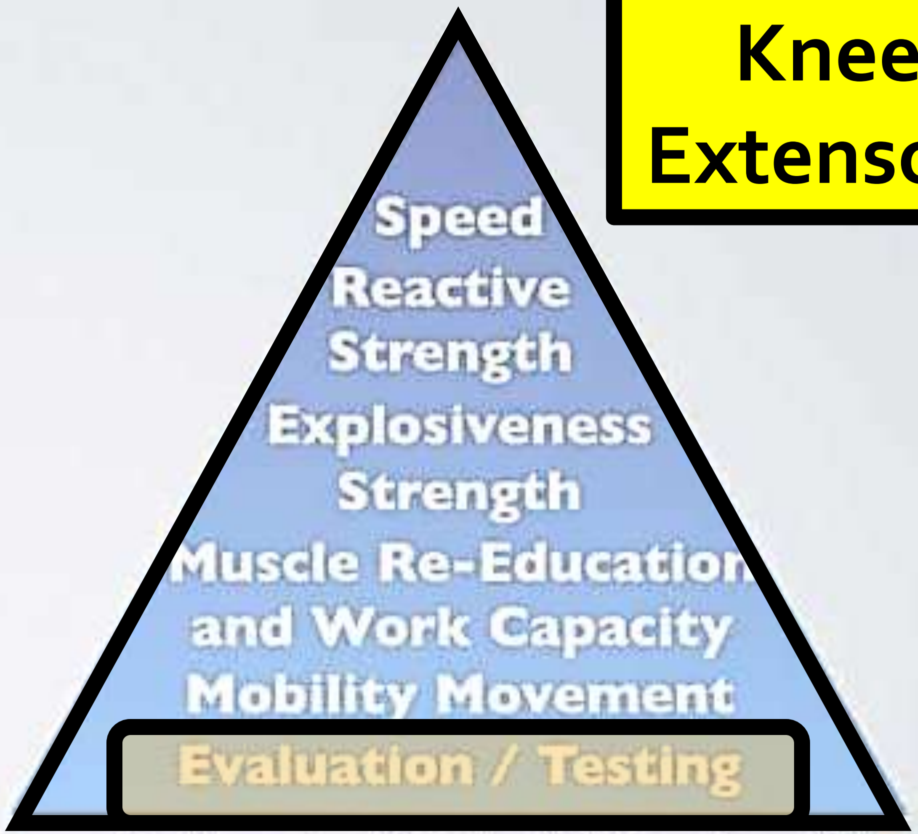


Brainstem inhibition
↓ Voluntary drive
Fear
↓ Quadriceps
AMI
Reduced alpha motoneuron excitability
Spinal Reflex Inhibition
Inflammation
Swelling
Joint laxity
Afferent disruption
+/- Extensor Mechanism
Joint damage


ETC.
CKC DF
PROPRIO
ETC.
TRICEPS SURAE
ROM
QUADRICEPS
"CORE"
PSYCH
EXPOSURES
GAIT
CV CAPACITY
HAMSTRINGS
GLUTES

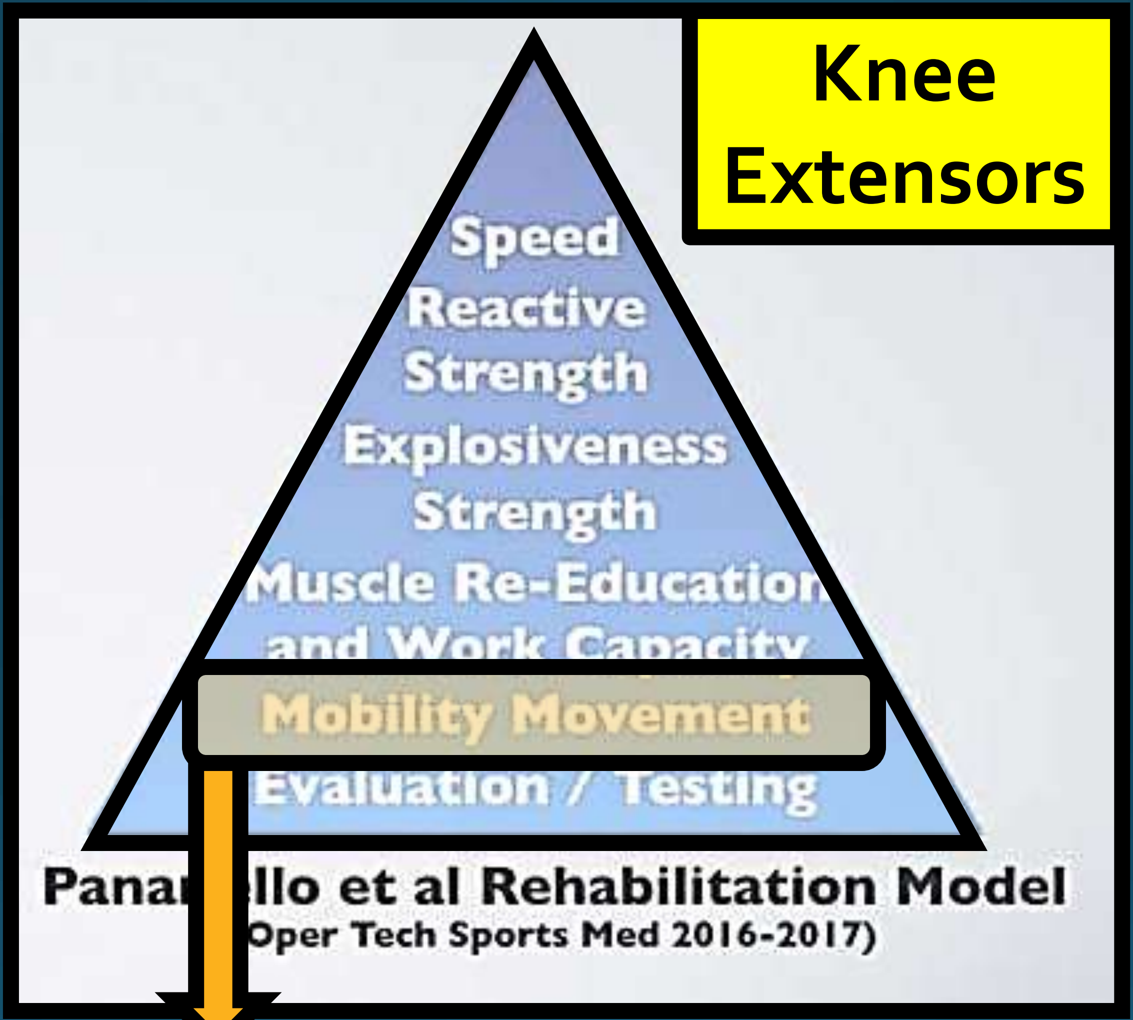

Hierarchy of Athletic Development
Speed
Reactive Strength
Explosiveness
Strength
Work Capacity
Evaluation / Testing
Vermeil Performance Model
Speed
Reactive Strength
Explosiveness
Strength
Muscle Re-Education and Work Capacity
Mobility Movement
Evaluation / Testing
Panariello et al Rehabilitation Model
(Oper Tech Sports Med 2016-2017)

Knee Extensors

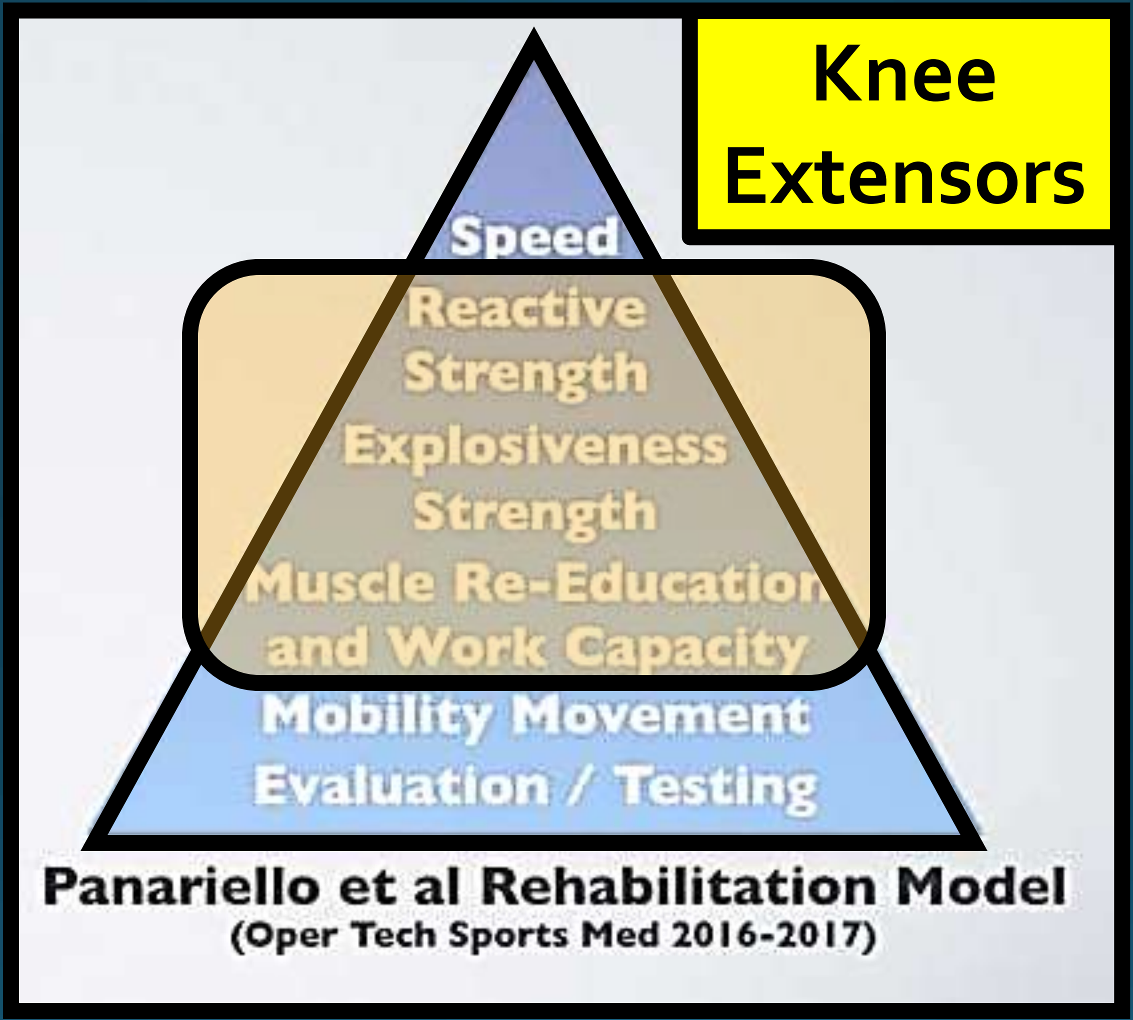


Panariello et al Rehabilitation Model
(Oper Tech Sports Med 2016-2017)

"Test, don't guess"


Knee Extensors
Speed
Reactive Strength
Explosiveness
Strength
Muscle Re-Education and Work Capacity
Mobility Movement
Evaluation / Testing
Panar llo et al Rehabilitation Model
(Oper Tech Sports Med 2016-2017)

Basics


Knee
Extensors
Speed
Reactive
Strength
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Strength
Muscle Re-Education
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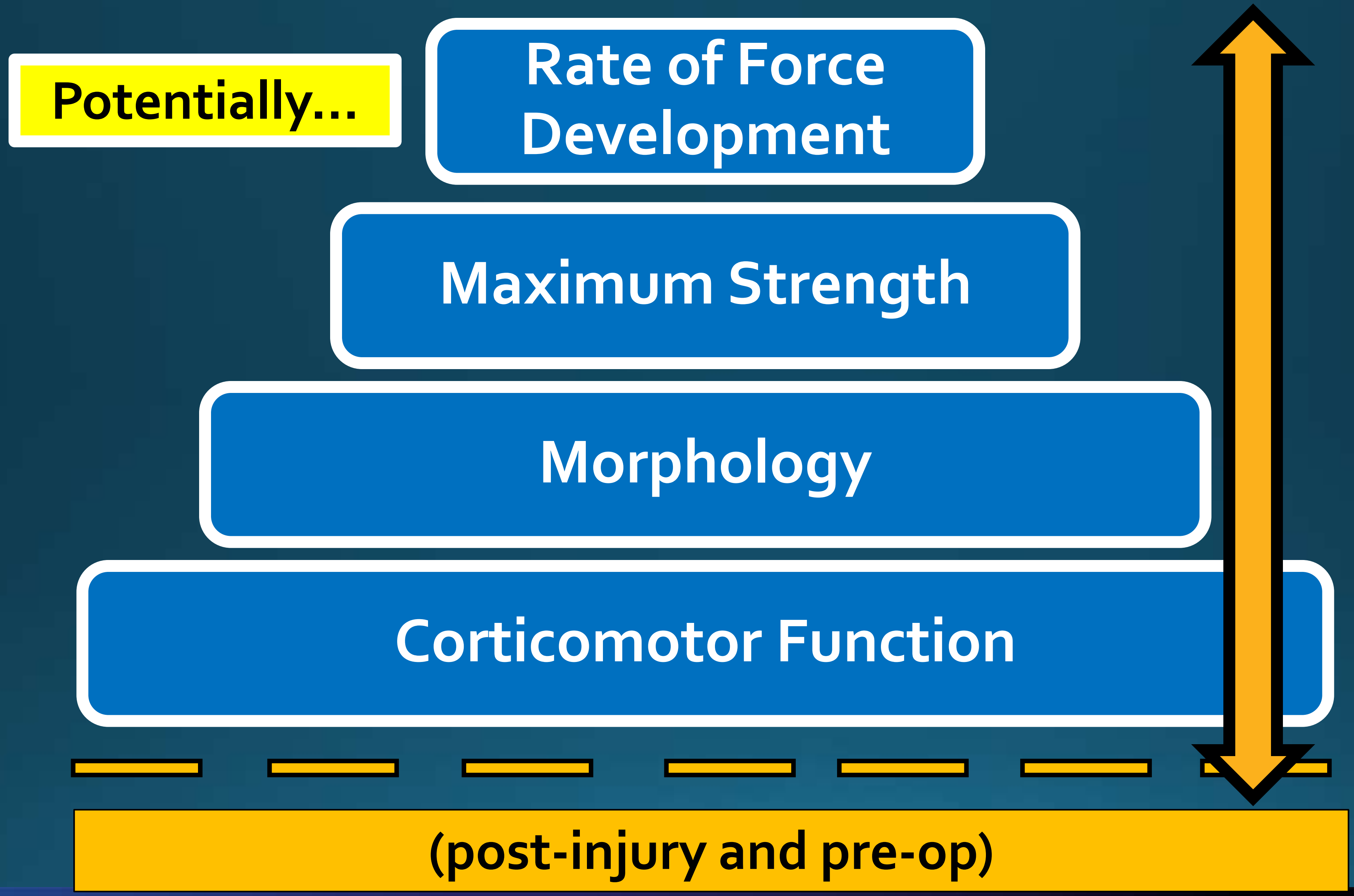
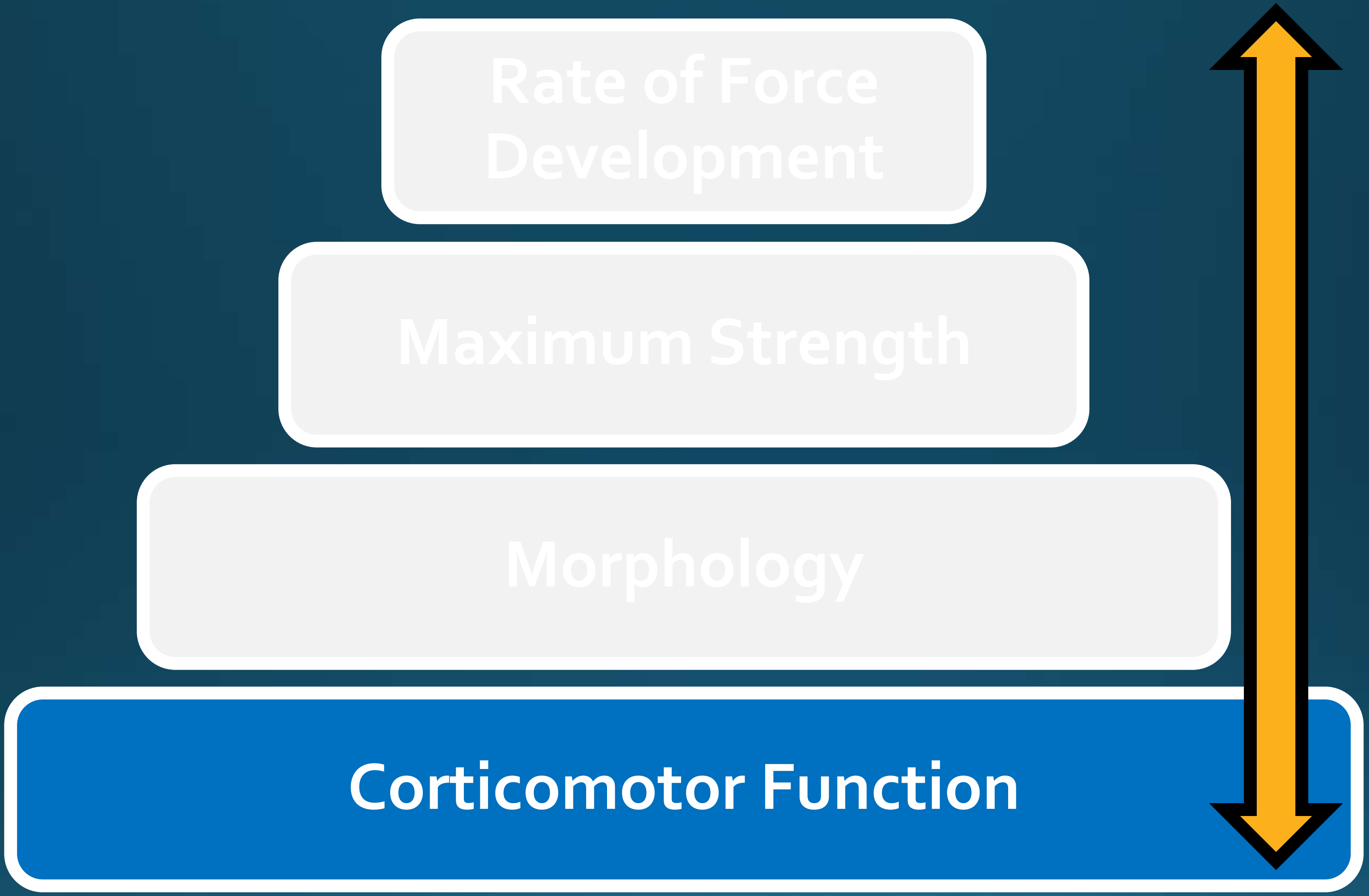
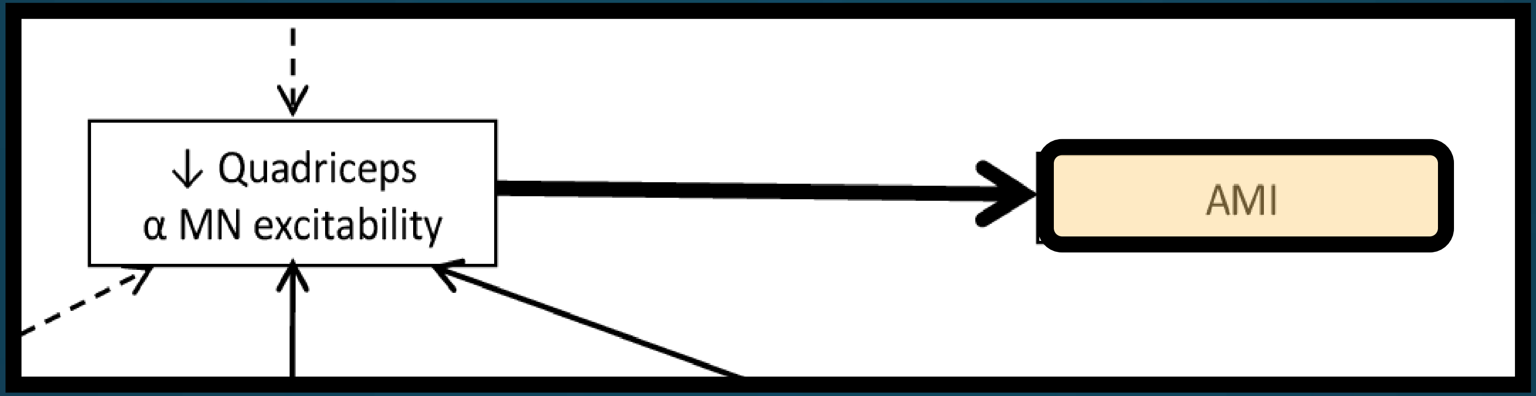
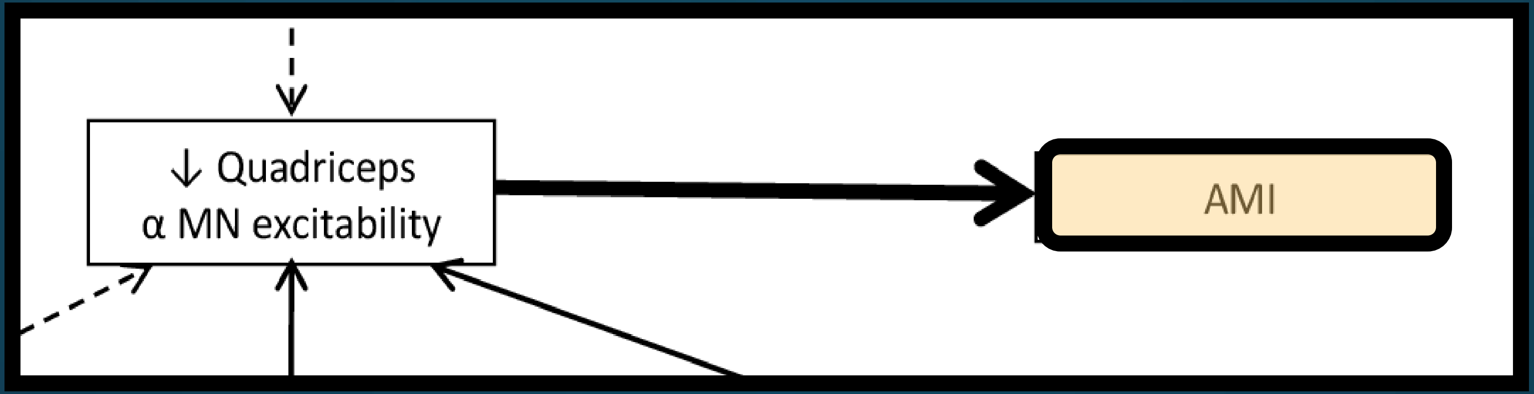

Potentially...
Rate of Force Development
Maximum Strength
Morphology
Corticomotor Function
(post-injury and pre-op)
TWIN CITIES ORTHOPEDICS
TRAINING HAUS


Rate of Force Development
Maximum Strength
Morphology
Corticomotor Function


↓ Quadriceps
α MN excitability
AMI


ON
OFF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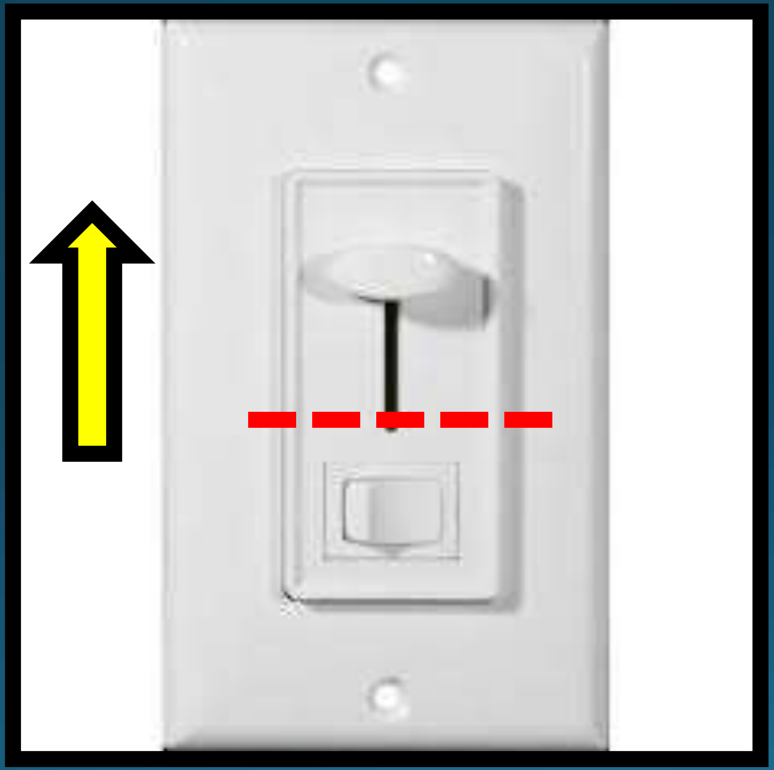
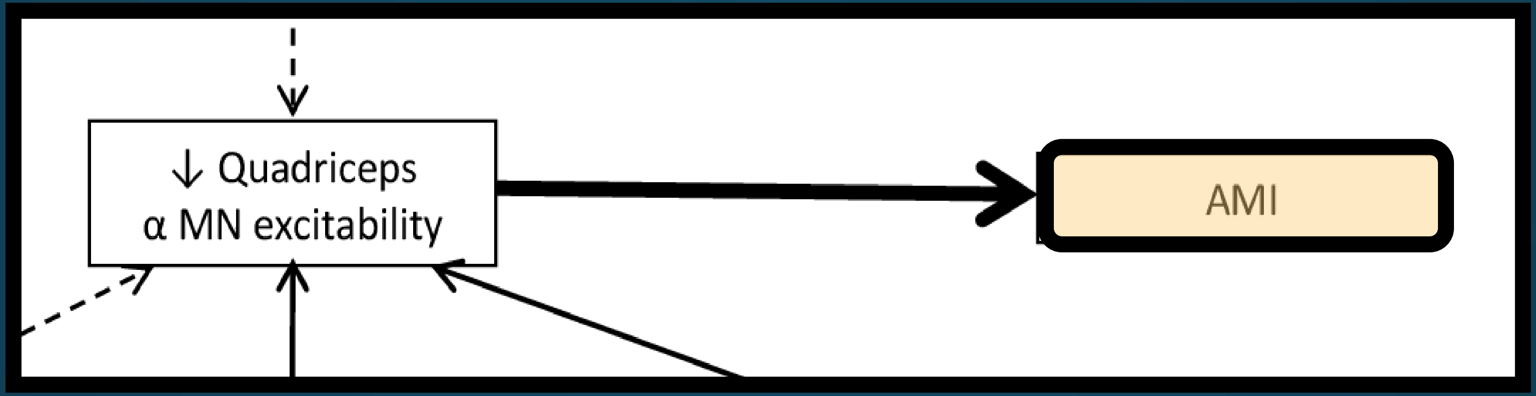



↓ Quadriceps
α MN excitability
AMI

Impaired Corticomotor Function

Scheurer SA. PhD Thesis: "The Relationship between Corticomotor Excitability and Quadriceps Neuromuscular Function in ACL Reconstructed Patients," May 2018 .

Impaired Corticomotor Function

Higher Active Motor Threshold

Scheurer SA. PhD Thesis: "The Relationship between Corticomotor Excitability and Quadriceps Neuromuscular Function in ACL Reconstructed Patients," May 2018 .

Impaired Corticomotor Function

Higher Active Motor Threshold

Increased Electro-mechanical Delay

Scheurer SA. PhD Thesis: "The Relationship between Corticomotor Excitability and Quadriceps Neuromuscular Function in ACL Reconstructed Patients," May 2018 .

Impaired Corticomotor Function

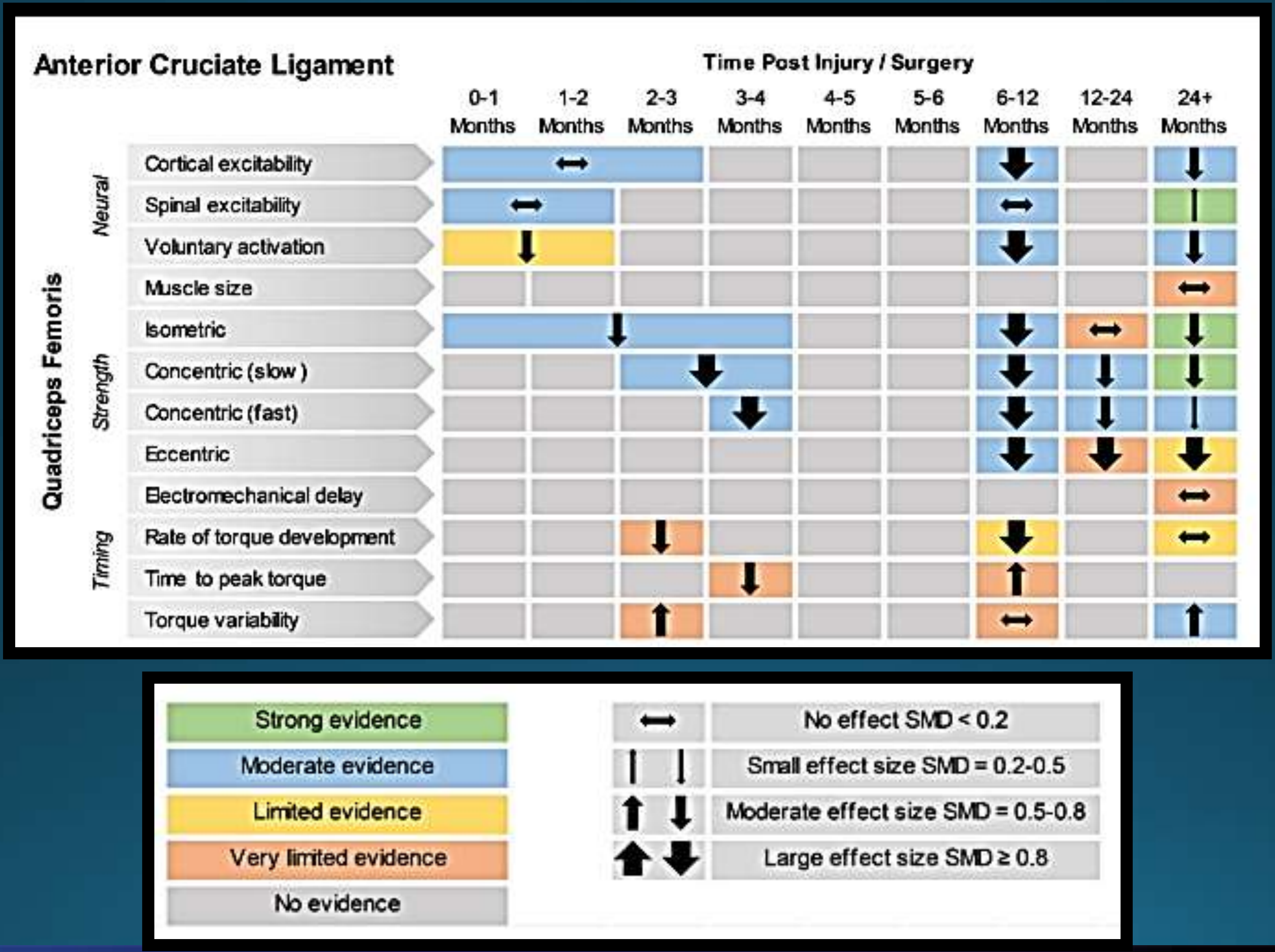
- Higher Active Motor Threshold
- Increased Electro-mechanical Delay
- Increased Coefficient of Variation

Scheurer SA. PhD Thesis: “The Relationship between Corticomotor Excitability and Quadriceps Neuromuscular Function in ACL Reconstructed Patients,” May 2018 .

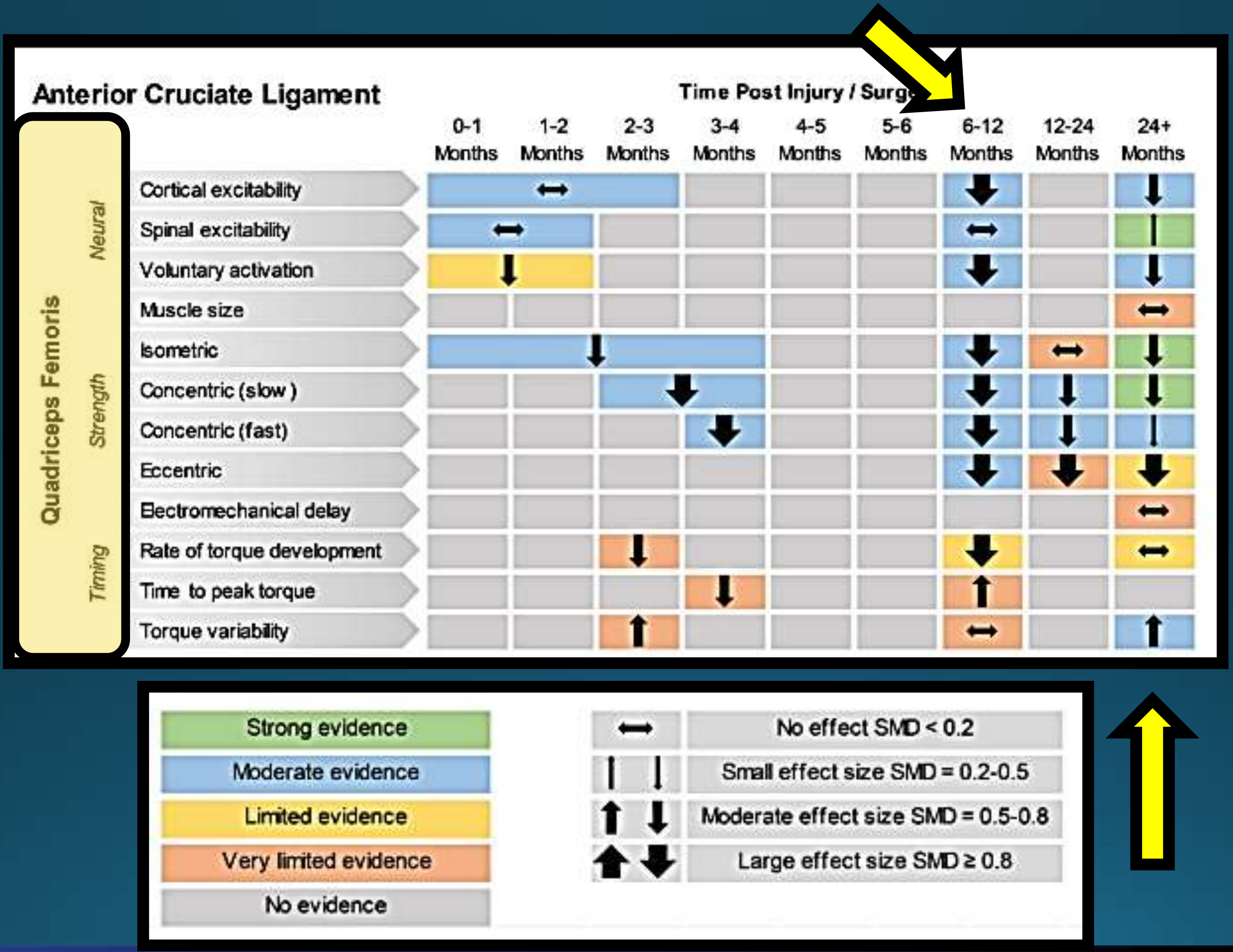
Impaired Corticomotor Function

- Higher Active Motor Threshold
- Increased Electro-mechanical Delay
- Increased Coefficient of Variation
- **Reduced Rate of Torque Development**

Scheurer SA. PhD Thesis: "The Relationship between Corticomotor Excitability and Quadriceps Neuromuscular Function in ACL Reconstructed Patients," May 2018 .



Tayfur B, et al. Neuromuscular Function of the Knee Joint Following Knee Injuries: Does It Ever Get Back to Normal? A Systematic Review with Meta-Analyses. Sports Medicine (2021) 51:321–338.



Tayfur B, et al. Neuromuscular Function of the Knee Joint Following Knee Injuries: Does It Ever Get Back to Normal? A Systematic Review with Meta-Analyses. Sports Medicine (2021) 51:321–338.

Impaired Corticomotor Function

Higher Active Motor Threshold

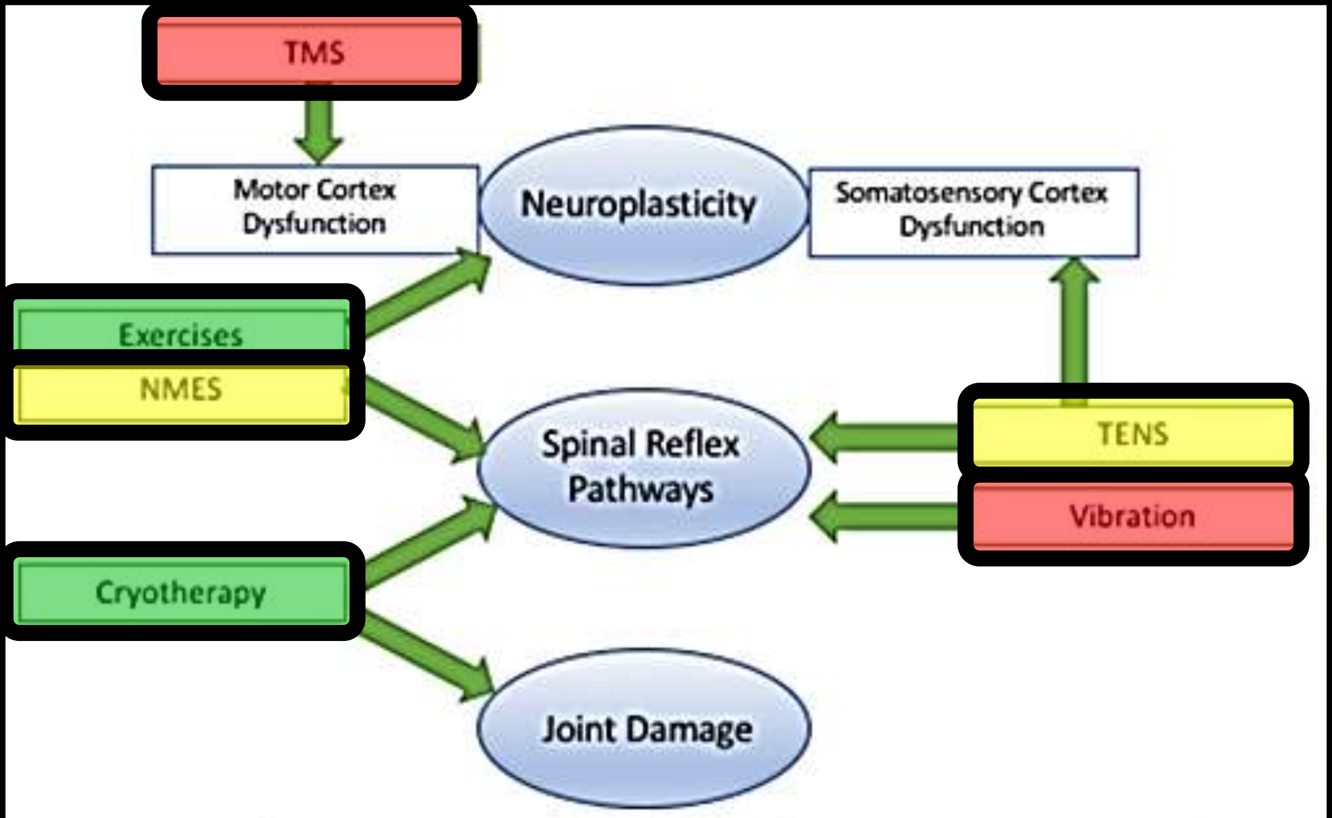
Scheurer SA. PhD Thesis: "The Relationship between Corticomotor Excitability and Quadriceps Neuromuscular Function in ACL Reconstructed Patients," May 2018 .

Review

OPEN ACCESS

Arthrogenic muscle inhibition after ACL reconstruction: a scoping review of the efficacy of interventions

Bertrand Sonnery-Cottet,[1] Adnan Saithna,[2,3] Benedicte Quelard,[4] Matt Daggett,[5] Amrut Borade,[1] Hervé Ouanezar,[1] Mathieu Thaunat,[1] William G Blakeney[1,6]



erapeutic interventions for arthrogenic muscle inhibition and their level of action. NMES, neuromuscular electrical stimulatio
us electrical nerve stimulation; TMS, transcranial magnetic stimulation.

Moderate
Low
Very Low

Journal of Athletic Training 2014;49(3):411–421
doi: 10.4085/1062-6050-49.1.04
© by the National Athletic Trainers' Association, Inc
www.natajournals.org

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

Focal knee joint cooling

- 20-30 min

Ice massage

- 20 min, 5x/wk, x 6 wks

Journal of Athletic Training 2014;49(3):411–421
doi: 10.4085/1062-6050-49.1.04

www.natajournals.org

systematic review

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Brian G. Pietrosimone, PhD, ATC

Focal knee joint cooling

Ice massage

Prior to "active" intervention

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www.natajournals.org

systematic review

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

Focal knee joint cooling

Ice massage

Not necessarily to reduce pain

Journal of Athletic Training 2014;49(3):411–421
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systematic review

Disinhibitory Interventions and Voluntary Quadriceps Activation: A Systematic Review

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TENS

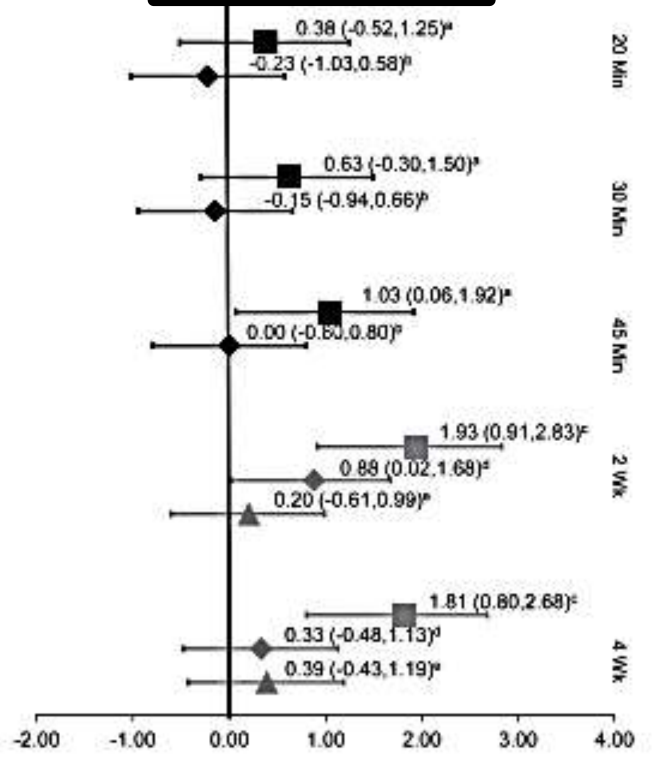


Figure 4. Transcutaneous electrical nerve stimulation (TENS) effect sizes. [a] Pietrosimone et al (2009)[32]: TENS; [b] Pietrosimone et al (2009)[32]: controls; [c] Pietrosimone et al (2011)[18]: TENS; [d] Pietrosimone et al (2011)[18]: placebo; [e] Pietrosimone et al (2011)[18]: exercise.

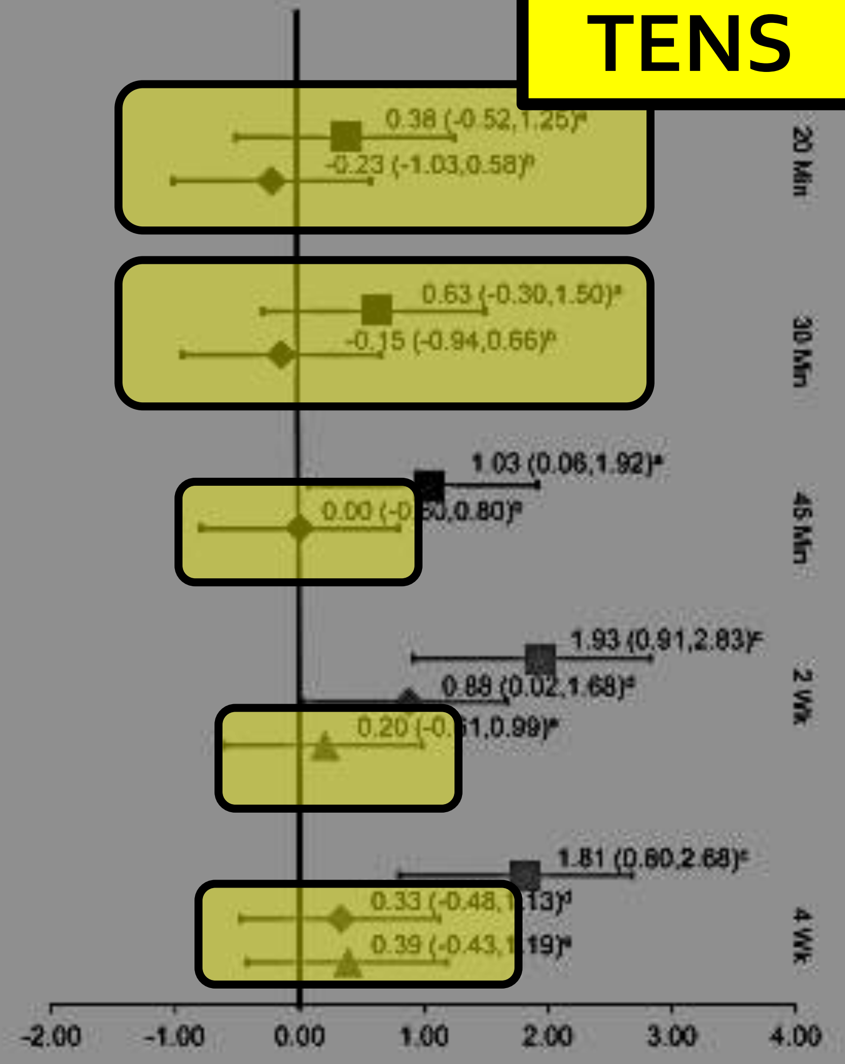
High Frequency

- 120-150 Hz
- .1-.15 second pulse width
  - < 10 min

Low Frequency

- 4 Hz
- 1 sec pulse width
  - 20-40 min, 2-3x/day

TENS



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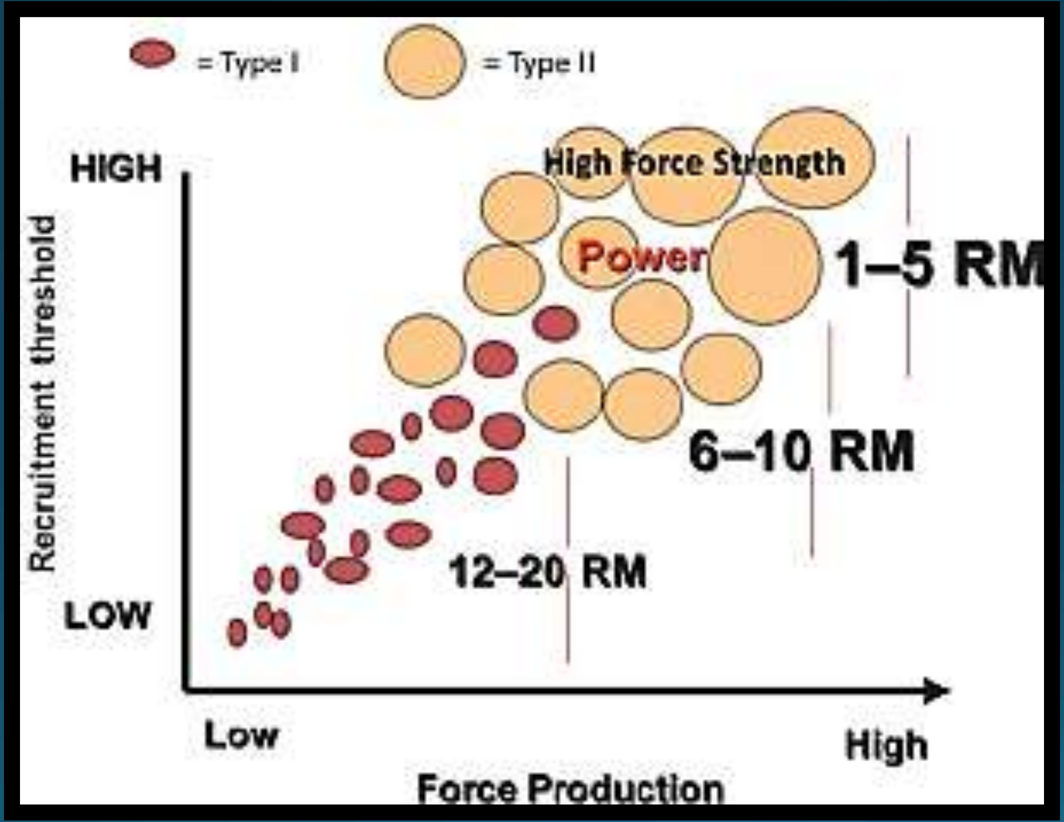
Impaired Corticomotor Function

- Increased Electro-mechanical Delay
- Increased Coefficient of Variation
- Reduced Rate of Torque Development

Scheurer SA. PhD Thesis: "The Relationship between Corticomotor Excitability and Quadriceps Neuromuscular Function in ACL Reconstructed Patients," May 2018 .

Henneman's Size Principle



CEU

Eccentric Exercise to Enhance Neuromuscular Control

Lindsey K. Lepley, PhD, ATC,*† Adam S. Lepley, PhD, ATC,† James A. Onate, PhD, ATC,‡ and Dustin R. Grooms, PhD, ATC§‖

Eccentric

(ec-cen-tric)

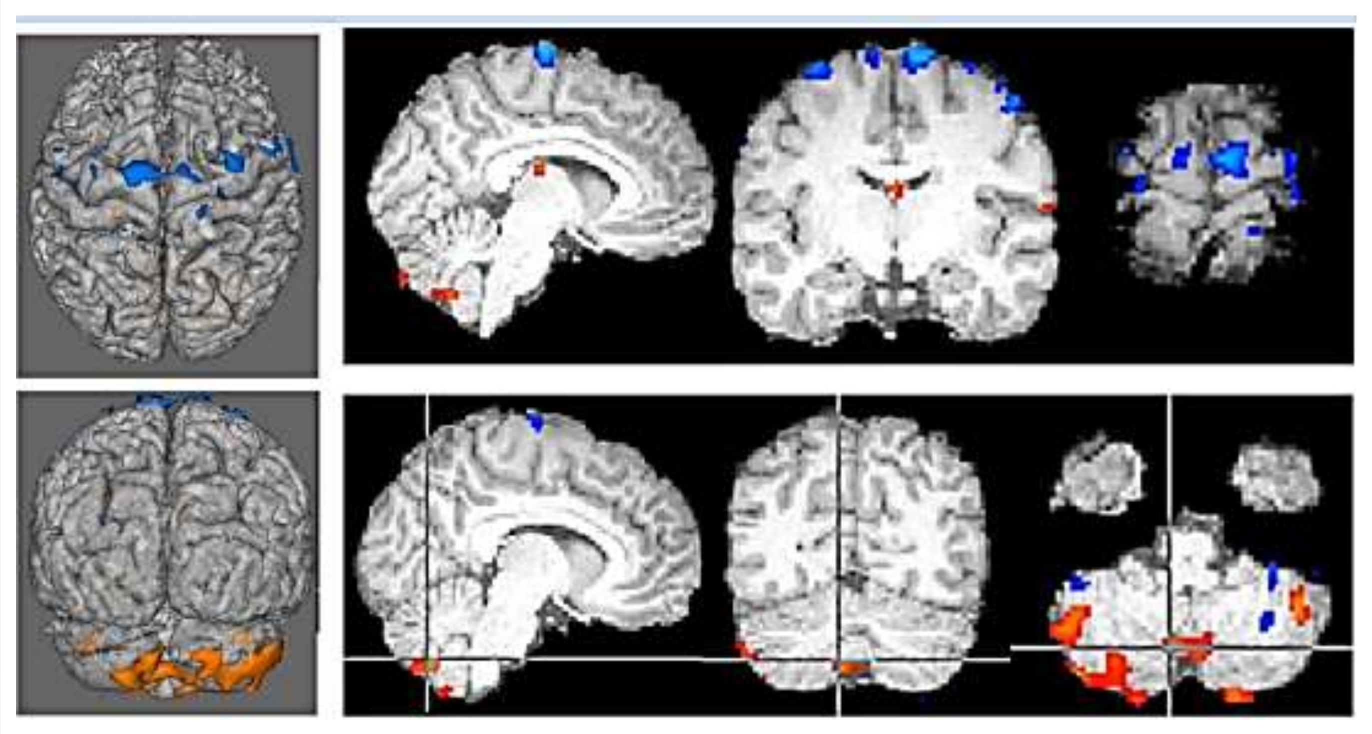
(adj) Deviating from conventional or accepted usage or conduct especially in odd or whimsical ways.

LaWhimsy//Word Nerd

CEU

Eccentric Exercise to Enhance Neuromuscular Control

Lindsey K. Lepley, PhD, ATC,[*†] Adam S. Lepley, PhD, ATC,[†] James A. Onate, PhD, ATC,[‡] and Dustin R. Grooms, PhD, ATC[§||]



Cross Education

Possible Mechanisms for the Contralateral Effects of Unilateral Resistance Training

Michael Lee and *Timothy J. Carroll*

School of Medical Sciences, Health and Exercise Science, University of New South Wales, Sydney, New South Wales, Australia

2.3.1 Modifications in Cortical Motor Pathways

Unilateral voluntary contractions can bring about complex changes in the state of cortical motor pathways controlling the contralateral homologous muscle. Motor-evoked potentials (MEPs) elicited by

Muellbacher et al.[41] have shown that the marked interhemispheric inhibition produced by an earlier conditioning TMS on the test MEP is almost completely abolished (i.e. becomes facilitated) when the contralateral homologous muscle is contracting at high force (>50% MVC). Using imaging tech-

2.3.2 Modifications in Spinal Pathways

High-force unilateral voluntary contractions are also known to affect the excitability of spinal motor pathways that project to the contralateral side. For

restricted to particular muscle groups, ages or genders. A recent meta-analysis determined that the magnitude of cross education is ≈7.8% of the initial strength of the untrained limb. While many features of cross education have been established, the underlying mechanisms are unknown.

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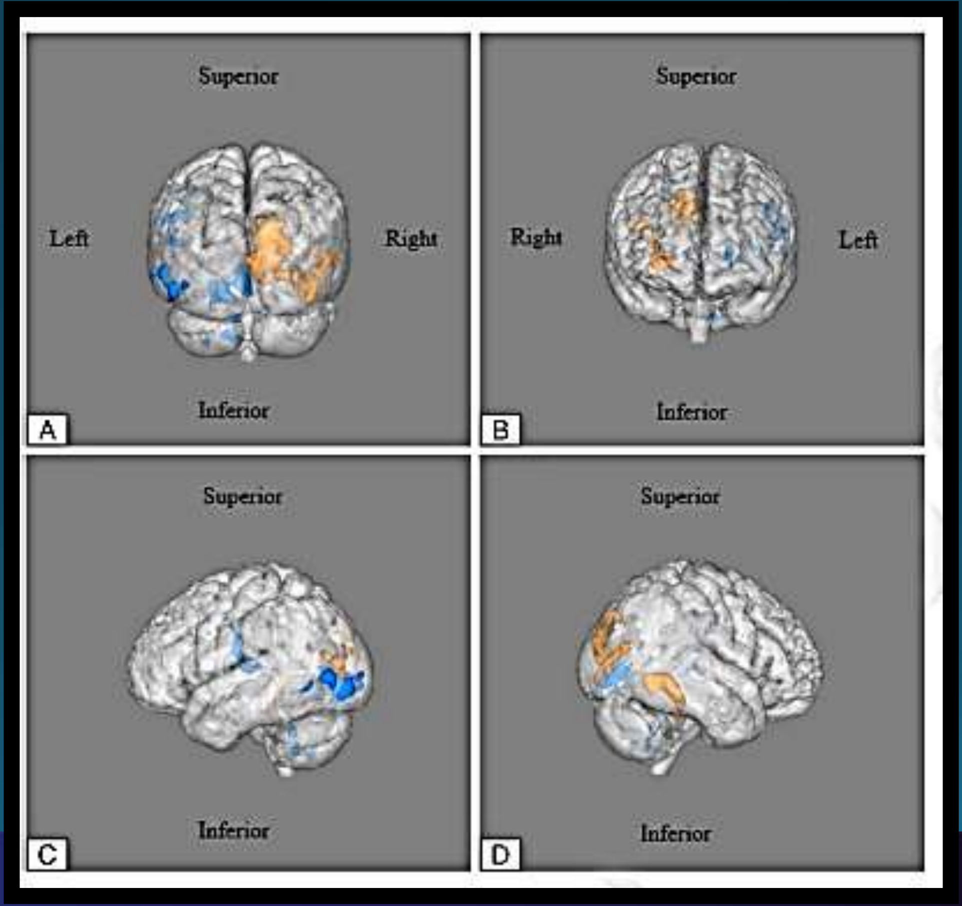
Journal of Sport Rehabilitation, (Ahead of Print)
https://doi.org/10.1123/jsr.2018-0026

Human Kinetics
ORIGINAL RESEARCH REPORT

The Effects of Attentional Focus on Brain Function During a Gross Motor Task

Louisa D. Raisbeck, Jed A. Diekfuss, Dustin R. Grooms, and Randy Schmitz



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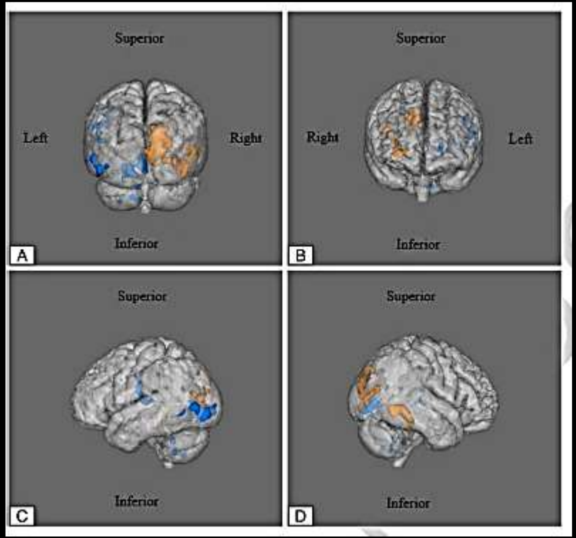


External focus >>> Internal Focus

Haggerty AL, et al. Neuroplastic Multimodal ACL Rehabilitation: INTEGRATING MOTOR LEARNING, VIRTUAL REALITY, AND NEUROCOGNITION INTO CLINICAL PRACTICE. Aspetar Sports Medicine Journal. 2021. August:66-70.

TWIN CITIES ORTHOPEDICS | TRAINING HAUS

NMES

Knee Pain and Mobility Impairments: Meniscal and Articular Cartilage Lesions Revision 2018

Knee Stability and Movement Coordination Impairments: Knee Ligament Sprain Revision 2017

2018 Recommendation

B Clinicians should provide neuromuscular stimulation/re-education to patients following meniscus procedures to increase quadriceps strength, functional performance, and knee function.

2017 Recommendation

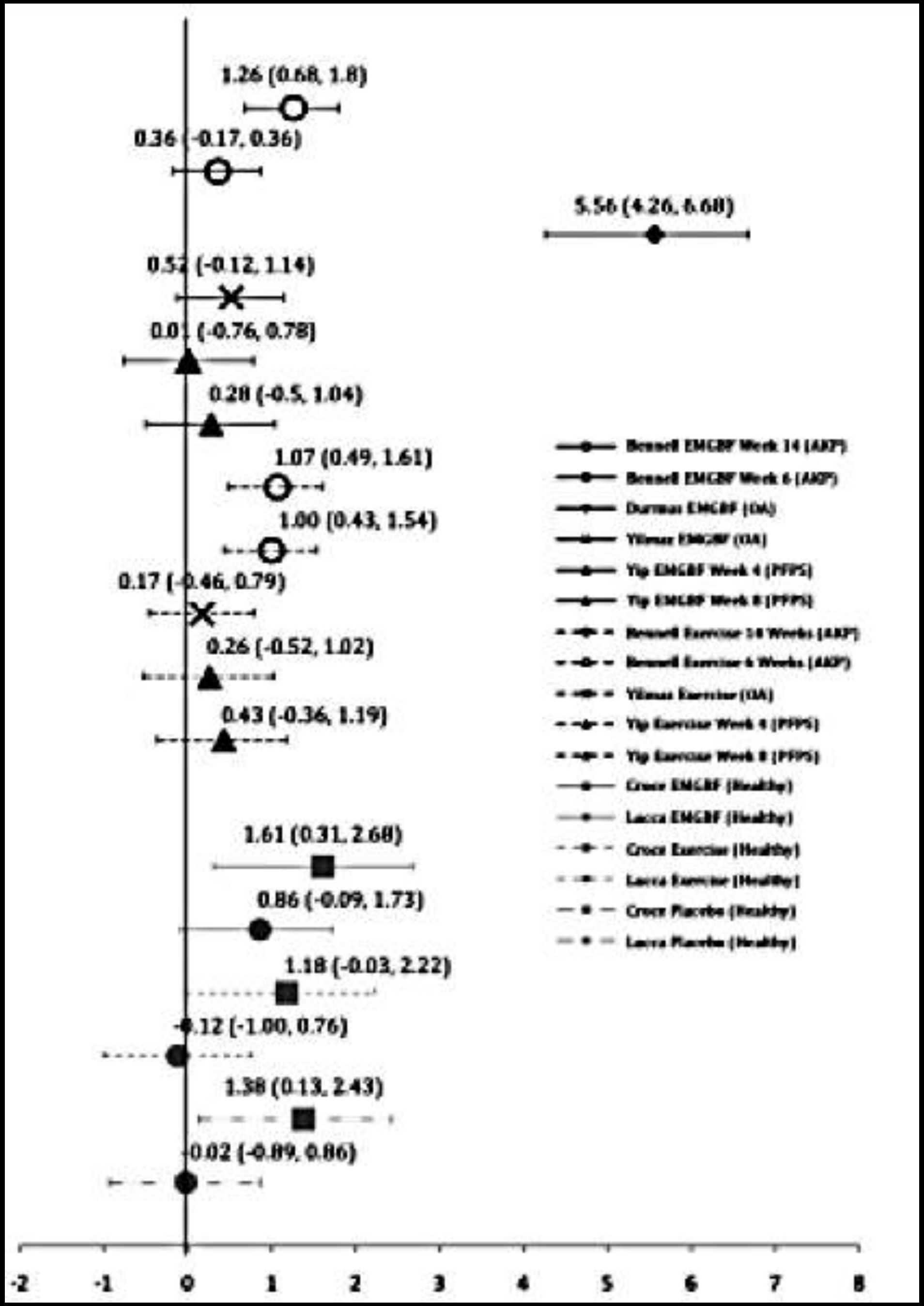
A Neuromuscular electrical stimulation should be used for 6 to 8 weeks to augment muscle strengthening exercises in patients after ACL reconstruction to increase quadriceps muscle strength and enhance short-term functional outcomes.

- **Duty Cycle**
  - 1:5 → 1:3
- **Phase Duration**
  - High 250-300 (µS)
- **Pulse Rate**
  - 35-50 pps
- **Amplitude**
  - Strong, yet tolerable
  - Progressive increase with each contraction
- **Electrode Size**
  - Large

A Comparison of Neuromuscular Electrical Stimulation Parameters for Postoperative Quadriceps Strength in Patients After Knee Surgery: A Systematic Review
Conley CEW, et al. Sports Health. 2021

Effects of Electromyographic Biofeedback on Quadriceps Strength: A Systematic Review

Adam S. Lepley, Phillip A. Gribble, and Brian G. Pietrosimone
Joint Injury and Muscle Activation Laboratory, Department of Kinesiology, University of Toledo, Toledo, Ohio



1.26 (0.68, 1.8)
0.36 (-0.17, 0.36)
5.56 (4.26, 6.68)
0.52 (-0.12, 1.14)
0.01 (-0.76, 0.78)
0.28 (-0.5, 1.04)
1.07 (0.49, 1.61)
1.00 (0.43, 1.54)
0.17 (-0.46, 0.79)
0.26 (-0.52, 1.02)
0.43 (-0.36, 1.19)
1.61 (0.31, 2.68)
0.86 (-0.09, 1.73)
1.18 (-0.03, 2.22)
-0.12 (-1.00, 0.76)
1.38 (0.13, 2.43)
0.02 (-0.89, 0.86)
Bennell EMGBF Week 14 (AKP)
Bennell EMGBF Week 6 (AKP)
Durmaz EMGBF (OA)
Yilmaz EMGBF (OA)
Yip EMGBF Week 4 (PFPS)
Yip EMGBF Week 8 (PFPS)
Bennell Exercise 14 Weeks (AKP)
Bennell Exercise 6 Weeks (AKP)
Yilmaz Exercise (OA)
Yip Exercise Week 4 (PFPS)
Yip Exercise Week 8 (PFPS)
Croce EMGBF (Healthy)
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Croce Exercise (Healthy)
Lacca Exercise (Healthy)
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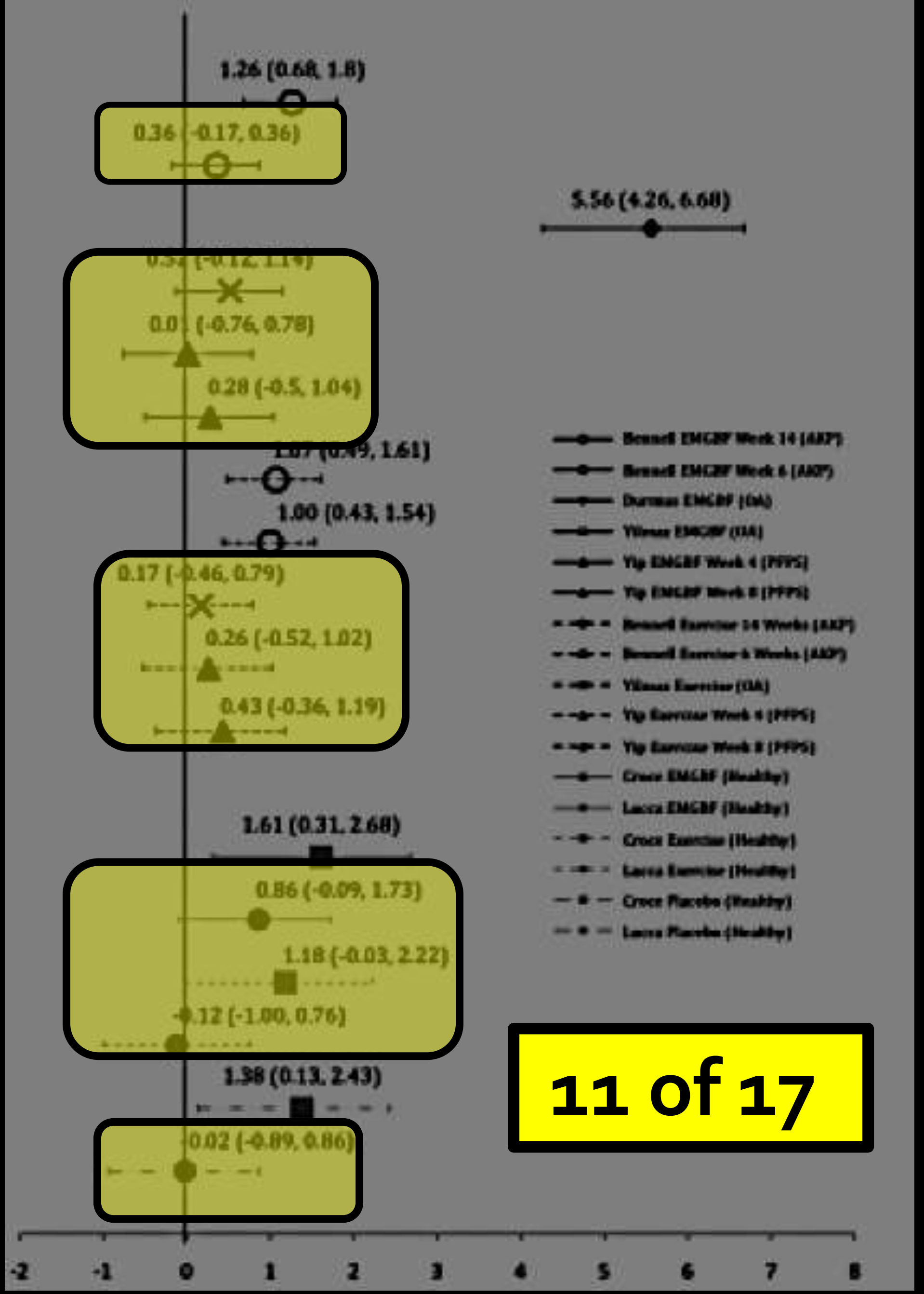
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Croce Placebo (Healthy)
Lacca Placebo (Healthy)
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11 of 17

Rate of Force Development

Maximum Strength

Morphology

Corticomotor Function

Manage effusion

Focal knee joint cooling

External Focus

NMES

Cross-education

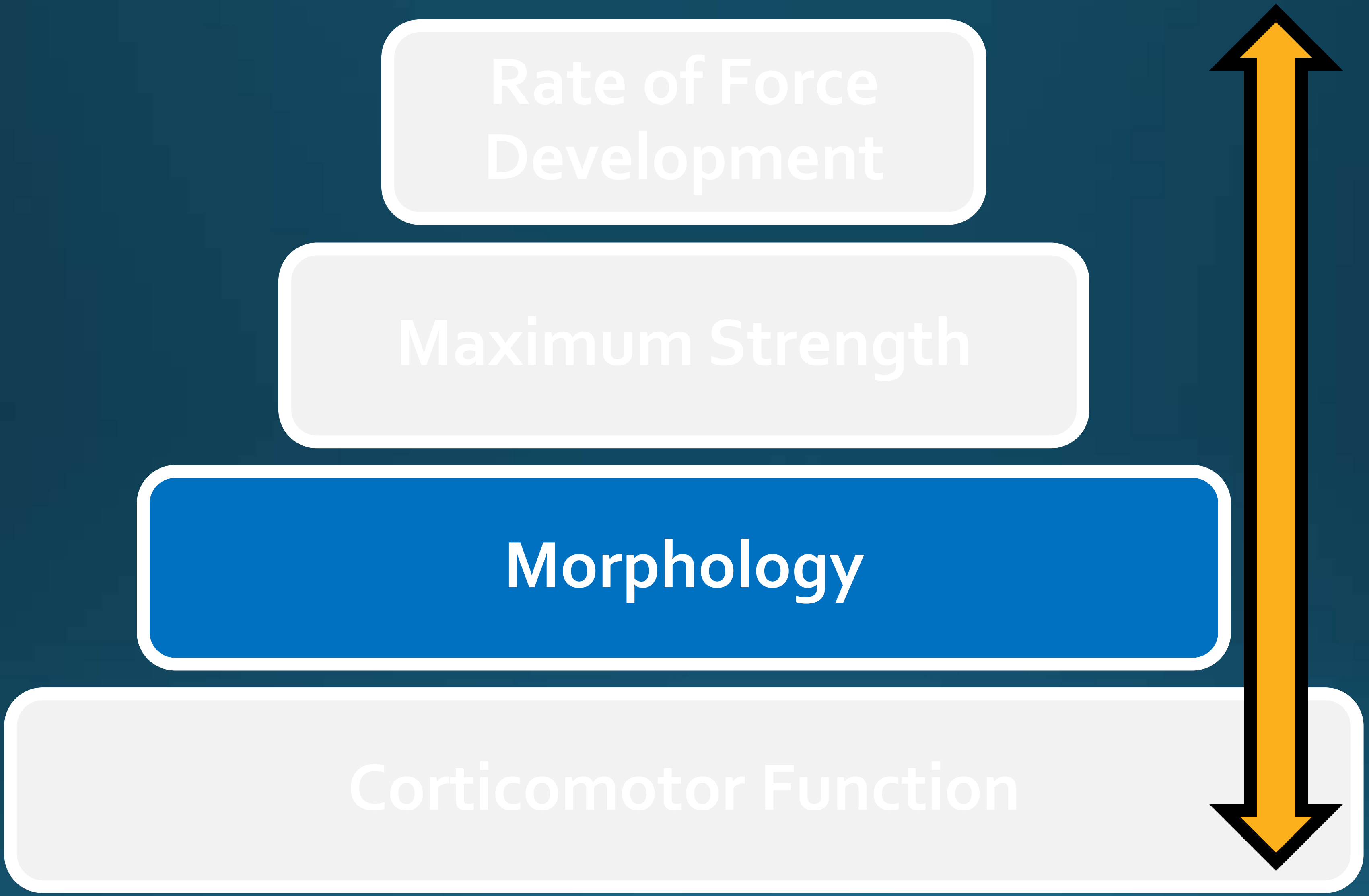
Eccentrics

Biofeedback

TENS

Corticomotor Function

Measure?


Rate of Force Development
Maximum Strength
Morphology
Corticomotor Function

Eur J Appl Physiol (2007) 99:283–289
DOI 10.1007/s00421-006-0346-y

ORIGINAL ARTICLE

Hip, thigh and calf muscle atrophy and bone loss after 5-week bedrest inactivity

Hans E. Berg · Ola Eiken · Lucijan Miklavcic · Igor B. Mekjavic

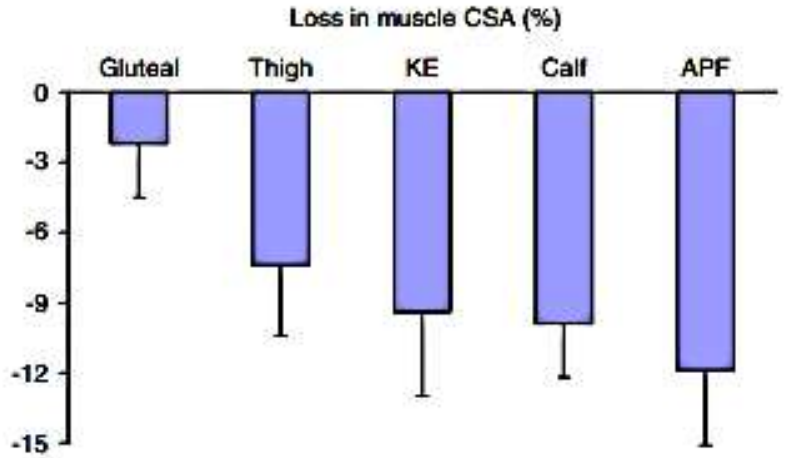


Fig. 1 Mean values of relative (%) change in cross-section area (*CSA*) of the thigh and calf muscle groups, and of the gluteal hip muscles, the knee extensors (*KE*) and the ankle-plantar flexors (*APF*). Values are means (SD); $n = 10$

Methods

Ten healthy males [25 (5) years, 1.80 (0.09) m, 70.5 (8.2) kg], who had given their written consent, completed 35 days of horizontal bedrest. Five healthy males [25 (5) years, 1.78 (0.09) m, 71.5 (22.3) kg] volunteered to serve as control subjects. The experimental

TWIN CITIES ORTHOPEDICS
TRAINING HAUS

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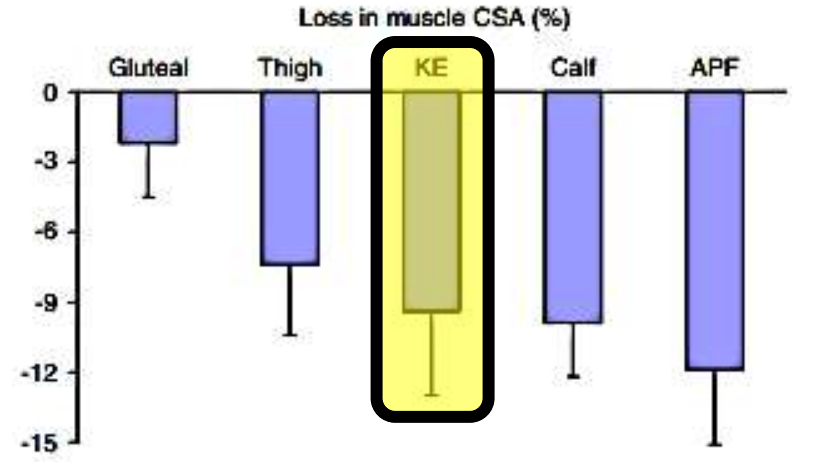
20% decrease in quadriceps strength ($P < 0.01$)



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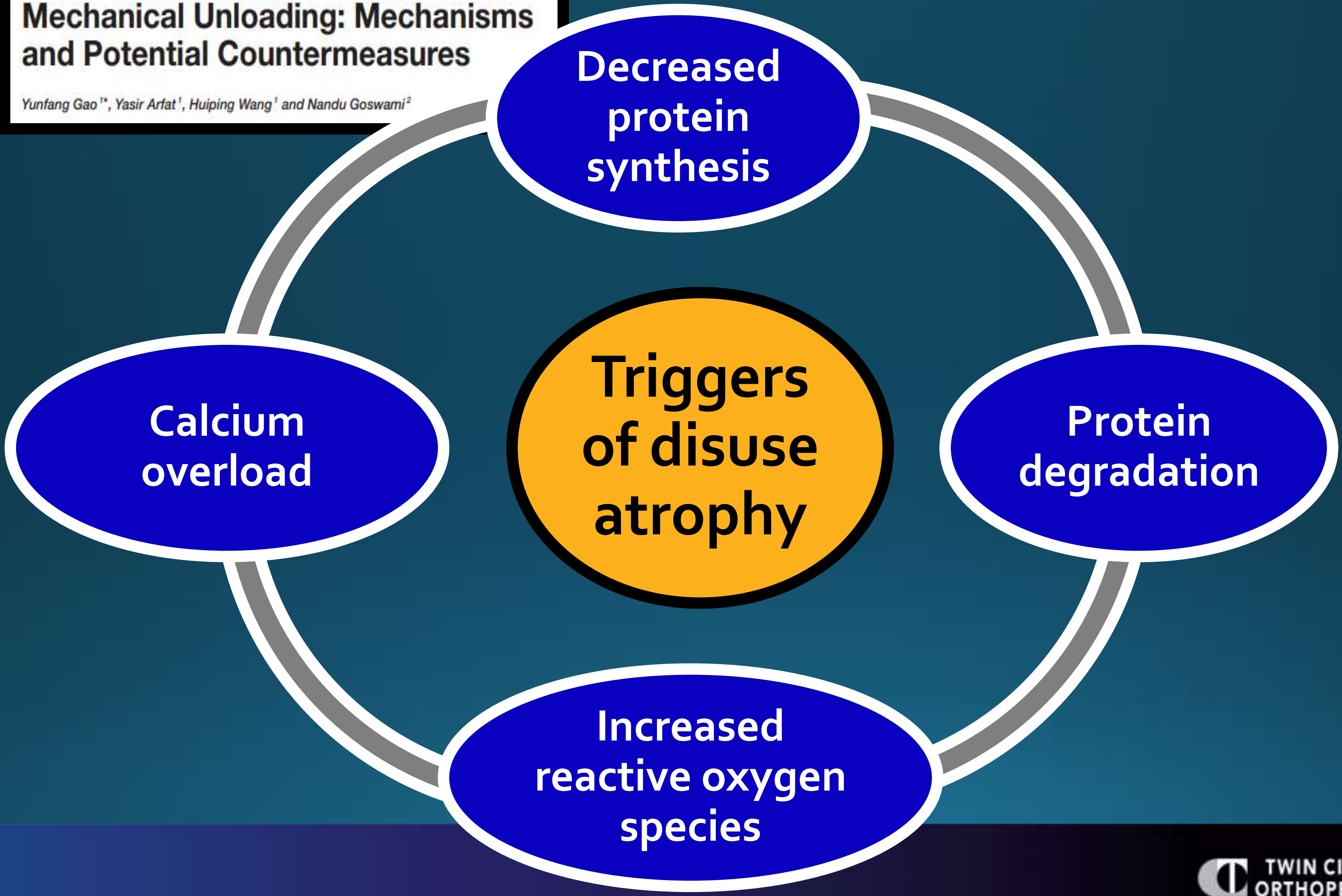
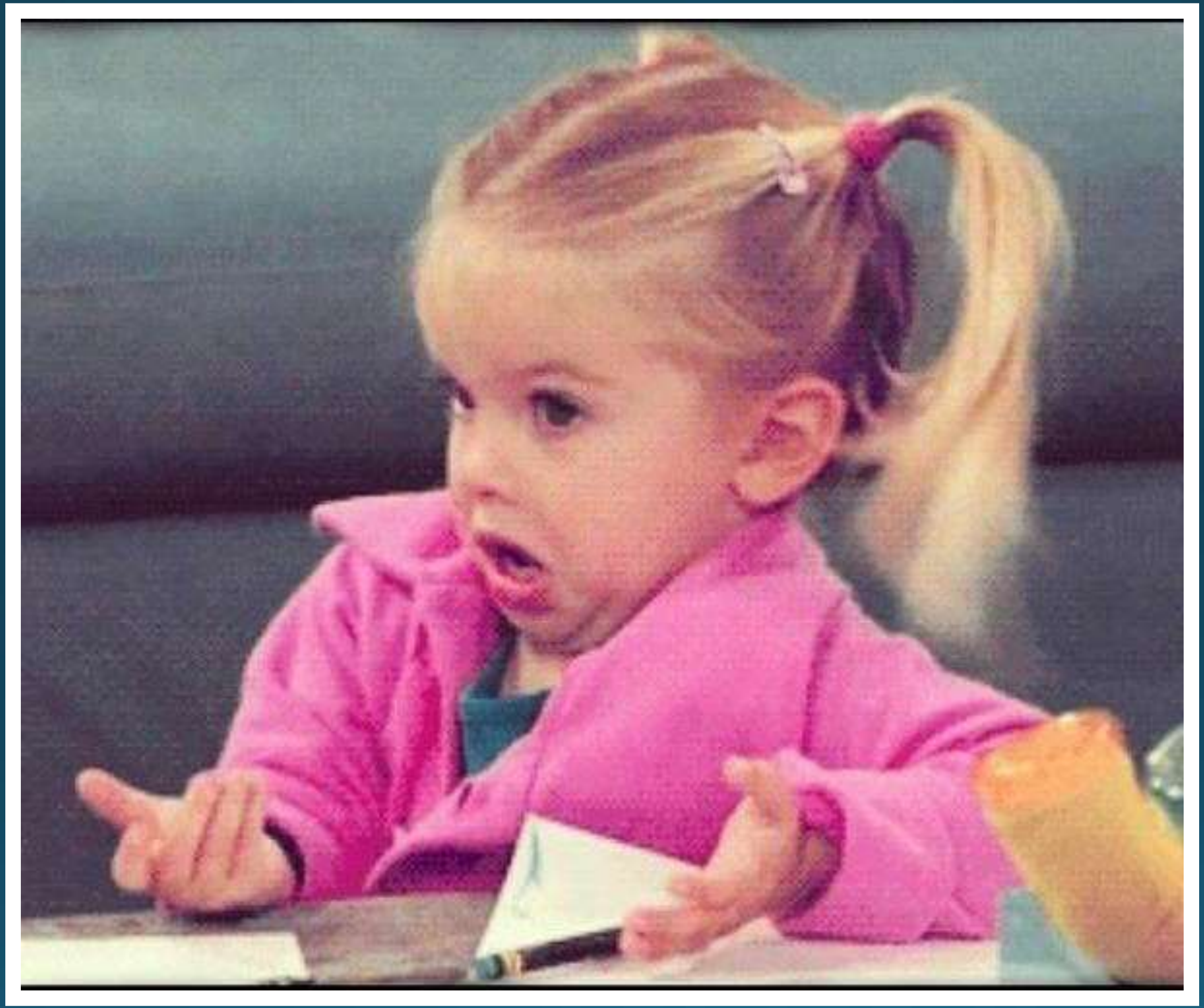
Muscle Atrophy Induced by Mechanical Unloading: Mechanisms and Potential Countermeasures

Yunfang Gao[1*], Yasir Arfat[1], Huiping Wang[1] and Nandu Goswami[2]





Muscle Atrophy Induced by Mechanical Unloading: Mechanisms and Potentia

Yunfang Gao[1*], Yasir Arfat[1], H

Nutrition Consult:

Remi Famodu, PhD, RDN, CSSD
Kaela Colvard, MS, RD, CSSD
Austin Voltin, MS, RD, CSSD

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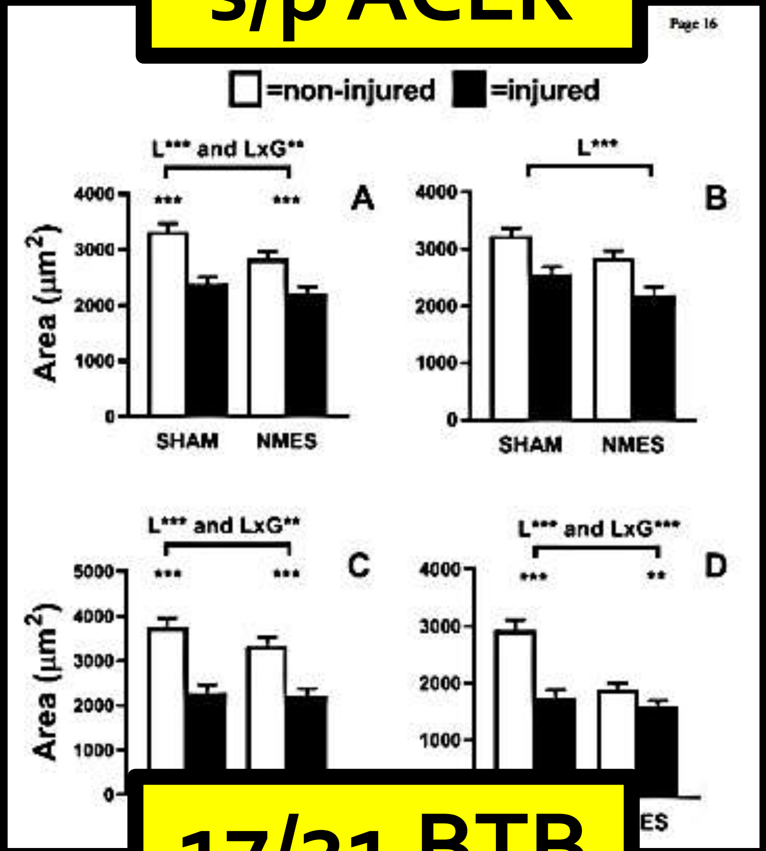
The American journal of sports medicine
Author Manuscript HHS Public Access

Utility of Neuromuscular Electrical Stimulation to Preserve Quadriceps Muscle Fiber Size and Contractility Following Anterior Cruciate Ligament Injury and Reconstruction: A Randomized, Sham-Controlled, Blinded Trial

Michael J. Toth, PhD, Timothy W. Tourville, PhD, ATC, [...], and Bruce D. Beynnon, PhD

s/p ACLR



17/21 BTB

TWIN CITIES ORTHOPEDICS
TRAINING HAUS

Introduction to Blood Flow Restriction (BFR) Training

Jon Schoenecker, PT, DPT, OCS, CSCS

June 2021

TWIN CITIES ORTHOPEDICS
TRAINING HAUS

Blood Flow Restriction Exercise: Considerations of Methodology, Application, and Safety

Stephen D. Patterson[1*], Luke Hughes[1], Stuart Warmington[2], Jamie Burr[3], Brendan R. Scott[4], Johnny Owens[5], Takashi Abe[6], Jakob L. Nielsen[7], Cleiton Augusto Libardi[8], Gilberto Laurentino[9], Gabriel Rodrigues Neto[10], Christopher Brandner[11], Juan Martin-Hernandez[12] and Jeremy Loenneke[6]

TABLE 1 | Model of exercise prescription with BFR-RE.

	Guidelines
Frequency	2–3 times a week (>3 weeks) or 1–2 times per day (1–3 weeks)
Load	20–40% 1RM
Restriction time	5–10 min per exercise (reperfusion between exercises)
Type	Small and large muscle groups (arms and legs/uni or bilateral)
Sets	2–4
Cuff	5 (small), 10 or 12 (medium), 17 or 18 cm (large)
Repetitions Pressure	(75 reps) – 30 × 15 × 15 × 15, or sets to failure 40–80% AOP
Rest between sets	30–60 s
Restriction form	Continuous or intermittent
Execution speed	1–2 s (concentric and eccentric)
Execution	Until concentric failure or when planned rep scheme is completed

Front. Physiol., 15 May 2019

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It seems to work well…

Progress to heavy loading

Be aware of any potential contraindications

Sports Med
https://doi.org/10.1007/s40279-018-0862-z

CrossMark

REVIEW ARTICLE

The Importance of Muscular Strength: Training Considerations

Timothy J. Suchomel[1] · Sophia Nimphius[2] · Christopher R. Bellon[3] · Michael H. Stone[4]

Table 2 The theoretical potential of resistance training methods to benefit hypertrophy, strength, and power

Resistance training method	Hypertrophy	Strength	Power
Bodyweight exercise	+	+	++
Machine-based exercise	++	++	++
Weightlifting derivatives	+++	+++	+++++
Plyometrics	+	++	++++
Eccentric training	+++++	+++++	++++
Potentiation complexes	[a]	+++	+++++
Unilateral exercise	+++	++	+++
Bilateral exercise	++++	++++	+++
Variable resistance	+++++	++++	++++
Kettlebell training	++	++	+++
Ballistic training	++	+++	+++++

Resistance training methods ranked on scale from +, meaning low potential and +++++, meaning high potential

Assigned exercises, volume-load prescription, and an athlete's relative strength may influence adaptations

[a]Limited research available

+ = low potential

+++++ = high potential

TWIN CITIES ORTHOPEDICS

TRAINING HAUS

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CrossMark

REVIEW ARTICLE

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TWIN CITIES ORTHOPEDICS | TRAINING HAUS

CURRENT OPINION

Training to Fatigue: The Answer for Standardization When Assessing Muscle Hypertrophy?

Scott J. Dankel[1] · Matthew B. Jessee[1] · Kevin T. Mattocks[1] · J. Grant Mouser[1] · Brittany R. Counts[1] · Samuel L. Buckner[1] · Jeremy P. Loenneke[1]

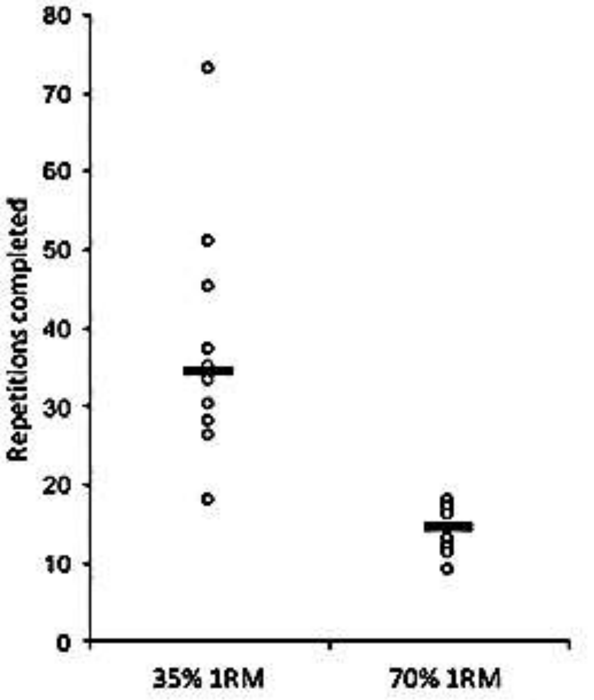

Fig. 1 Individual variability in repetitions to volitional fatigue for the elbow flexion exercise at two different relative loads. *Circles* represent each individual, with *solid lines* representing the group median. Notably, repetitions completed at 35 % 1RM ranged from 18 to 73, and at 70 % ranged from 9 to 18. The repetitions at 35 % [23] and 70 % [24] were obtained from two previous studies in our laboratory. *1RM* one-repetition maximum

TWIN CITIES ORTHOPEDICS

TRAINING HAUS

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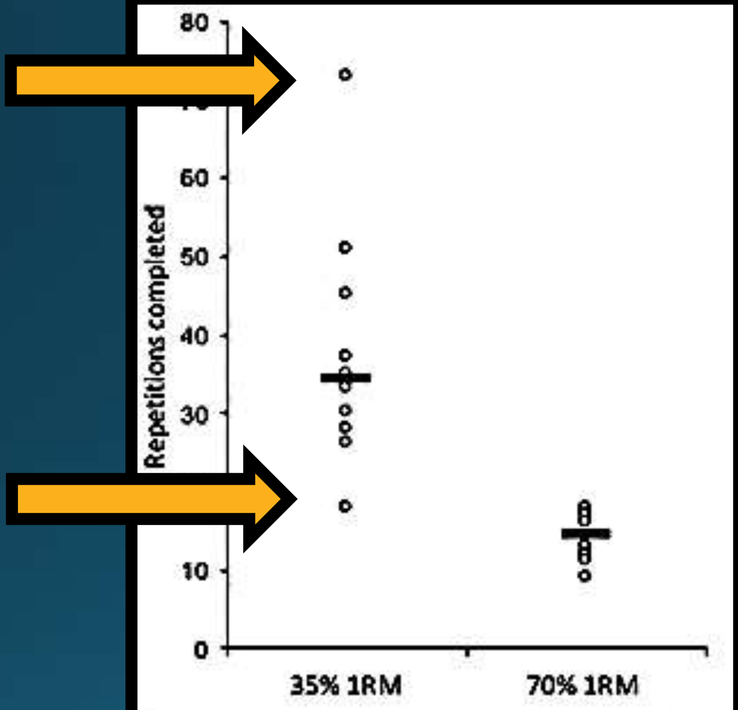

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- "…the most appropriate way to ensure all individuals are given a common stimulus is to prescribe exercise to *volitional fatigue*…"

CURRENT OPINION

Training to Fatigue: The Answer for Standardization When Assessing Muscle Hypertrophy?

Scott J. Dankel[1] · Matthew B. Jessee[1] · Kevin T. Mattocks[1] · J. Grant Mouser[1] · Brittany R. Counts[1] · Samuel L. Buckner[1] · Jeremy P. Loenneke[1]

Train to "Momentary Muscle Failure"

International Journal of Strength and Conditioning

2021

Resistance Training Recommendations to Maximize Muscle Hypertrophy in an Athletic Population: Position Stand of the IUSCA

Brad J. Schoenfeld[1], James P. Fisher[2], Jozo Grgic[3], Cody T. Haun[4], Eric R. Helms[5], Stuart M. Phillips[6], James Steele[2] & Andrew D. Vigotsky[7]

"The recommendations represent a consensus of a consortium of experts in the field, based on the best available current evidence."

Table 1. Summary of Consensus Recommendations

Variable	CONSENSUS RECOMMENDATION
LOAD	• Individuals can achieve comparable muscle hypertrophy across a wide spectrum of loading zones. • There may be a practical benefit to prioritizing the use of moderate loads for the majority of sets in a hypertrophy-oriented training program. • Preliminary evidence suggests a potential hypertrophic benefit to employing a combination of loading ranges. This can be accomplished through a variety of approaches, including varying repetition ranges within a session from set to set, or by implementing periodization strategies with specific 'blocks' devoted to training across different loading schemes.
VOLUME	• A dose of approximately 10 sets per muscle per week would seem to be a general minimum prescription to optimize hypertrophy, although some individuals may demonstrate a substantial hypertrophic response on somewhat lower volumes. • Evidence indicates potential hypertrophic benefits to higher volumes, which may be of particular relevance to underdeveloped muscle groups. • Although empirical evidence is lacking, there may be a benefit to periodizing volume to increase systematically over a training cycle. • It may be prudent to limit incremental increases in the number of sets for a given muscle group to 20% of an athlete's previous volume during a given training cycle (~4 weeks) and then readjust accordingly.
FREQUENCY	• Significant hypertrophy can be achieved when training a muscle group as infrequently as once per week in lower to moderate volume protocols; there does not seem to be a hypertrophic benefit to greater weekly per-muscle training frequencies provided set volume is equated. • It may be advantageous to spread out volume over more frequent sessions when performing higher volume programs. A general recommendation would be to cap per-session volume at ~10 sets per muscle and, when applicable, increase weekly frequency to distribute additional volume.

Table 1. Summary of Consensus Recommendations

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LOAD	• Individuals can achieve comparable muscle hypertrophy across a wide spectrum of loading zones. • There may be a practical benefit to prioritizing the use of moderate loads for the majority of sets in a hypertrophy-oriented training program. • Preliminary evidence suggests a potential hypertrophic benefit to employing a combination of loading ranges. This can be accomplished through a variety of approaches, including varying repetition ranges within a session from set to set, or by implementing periodization strategies with specific 'blocks' devoted to training across different loading schemes.
VOLUME	• A dose of approximately 10 sets per muscle per week would seem to be a general minimum prescription to optimize hypertrophy, although some individuals may demonstrate a substantial hypertrophic response on somewhat lower volumes. • Evidence indicates potential hypertrophic benefits to higher volumes, which may be of particular relevance to underdeveloped muscle groups. • Although empirical evidence is lacking, there may be a benefit to periodizing volume to increase systematically over a training cycle. • It may be prudent to limit incremental increases in the number of sets for a given muscle group to 20% of an athlete's previous volume during a given training cycle (~4 weeks) and then readjust accordingly.
FREQUENCY	• Significant hypertrophy can be achieved when training a muscle group as infrequently as once per week in lower to moderate volume protocols; there does not seem to be a hypertrophic benefit to greater weekly per-muscle training frequencies provided set volume is equated. • It may be advantageous to spread out volume over more frequent sessions when performing higher volume programs. A general recommendation would be to cap per-session volume at ~10 sets per muscle and, when applicable, increase weekly frequency to distribute additional volume.

REST INTERVAL	• As a general rule, rest periods should last at least 2 minutes when performing multi-joint exercises. • Shorter rest periods (60-90 secs) can be employed for single-joint and certain machine-based exercises.
EXERCISE SELECTION	• Hypertrophy-oriented RT programs should include a variety of exercises that work muscles in different planes and angles of pull to ensure complete stimulation of the musculature. • Programming should employ a combination of multi- and single-joint exercises to maximize whole muscle development. Where applicable, focus on employing exercises that work muscles at long lengths. • Free-weight exercises with complex movement patterns should be performed regularly to reinforce motor skills. Alternatively, less complex exercises can be rotated more liberally for variety. • Attention must be given to applied anatomical and biomechanical considerations so that exercise selection is not simply a collection of diverse exercises, but rather a cohesive, integrated strategy designed to target the entire musculature.
SET END POINT	• Novice lifters can achieve robust gains in muscle mass without training at a close proximity to failure. As an individual gains training experience, the need to increase intensity of effort appears to become increasingly important. • Highly trained lifters may benefit from taking some sets to momentary muscular failure. In such cases, its use should be employed somewhat conservatively, perhaps limiting application to the last set of a given exercise. • Confining the use of failure training primarily to single-joint movements and machine-based exercises may help to manage the stimulus-fatigue ratio and thus reduce potential negative consequences on recuperation. • Older athletes should employ failure training more sparingly to allow for adequate recovery. • Periodizing failure training may be a viable option, whereby very high levels of effort are employed liberally prior to a peaking phase, and then followed by a tapering phase involving reduced levels of effort.

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IJSPT

CLINICAL COMMENTARY

ENERGY SYSTEM DEVELOPMENT AND LOAD MANAGEMENT THROUGH THE REHABILITATION AND RETURN TO PLAY PROCESS

Scot Morrison, PT, DPT, OCS, CSCS[1,2]
Patrick Ward, MS, CSCS, LMT[3]
Gregory R duManoir, PhD[4]

2017

Table 4. *Energy System Training Parameters*

	Work Interval		Recovery		Series		Adaptation
	Intensity	*Duration*	*Intensity*	*Duration*	*Number of Series*	*Weekly Frequency*	*Timeframe*
Short Duration – Repeated Efforts							
Explosive Effort	Maximal	<6 s	Passive	30 to 120 s	2 to 6	2 to 3	2 to 3 weeks
High-Intensity Effort	Maximal	15 to 30 s	RPE <2	30 to 120 s	4 to 10	2 to 3	2 to 3 weeks
Endurance Effort	RPE 8 to 9	2-3 min	RPE <2	2-3 min	6 to 10	2 to 3	2 to 3 weeks
Long Duration – Endurance							
Extensive	Zone 1	20-60 min	Continuous			3 to 5	2 weeks to 3 months
Intensive	Zone 2 Zone 3	6-8 min 4-6 min	Low Zone 1	2-4 min	3 to 6	2 to 3	2+ weeks

TWIN CITIES ORTHOPEDICS | TRAINING HAUS

Review

Implementing Eccentric Resistance Training—Part 1: A Brief Review of Existing Methods

Timothy J. Suchomel [1,2,*], John P. Wagle [3], Jamie Douglas [4], Christopher B. Taber [5], Mellissa Harden [2,6], G. Gregory Haff [2,7] and Michael H. Stone [8]

Table 1. Summary of underlying eccentric training effects that may benefit hypertrophy, strength, and power output.

Hypertrophy	Strength	Power Output
↑ Anabolic signaling ↑ Satellite cell activation ↑ Motor unit recruitment ↑ Activation of motor cortex ↑ Force production capacity Possible ↑ fast twitch motor unit preferential recruitment	↑ Motor unit recruitment ↑ Activation of motor cortex ↑ Force production ↑ Motor unit discharge rate ↑ MTU stiffness ↓ Regulation of inhibitory reflexes Possible ↑ fast twitch motor unit preferential recruitment Possible ↑ type IIx fiber composition (phenotype shift)	↑ Motor unit recruitment ↑ Activation of motor cortex ↑ Force production capacity ↑ Motor unit discharge rate ↑ MTU stiffness ↓ Regulation of inhibitory reflexes ↑ Muscle fascicle length Possible ↑ fast twitch motor unit preferential recruitment Possible ↑ type IIx fiber composition (phenotype shift) Possible ↑ excitation–contraction coupling rates ↑ Muscle fiber shortening velocity

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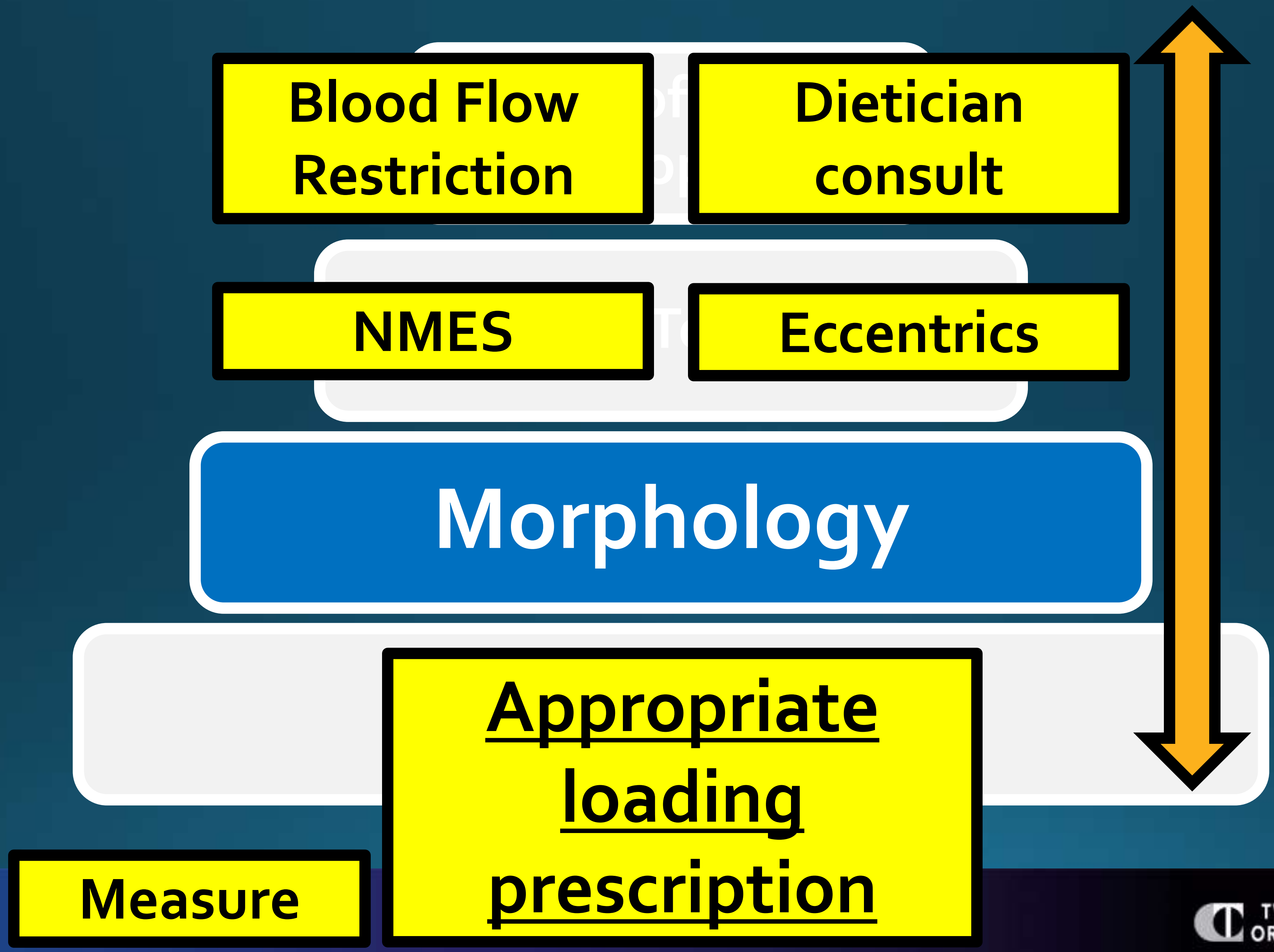
Hypertrophy
↑ Anabolic signaling
↑ Satellite cell activation
↑ Motor unit recruitment
↑ Activation of motor cortex
↑ Force production capacity
Possible ↑ fast twitch motor unit preferential recruitment

Rate of Force Development

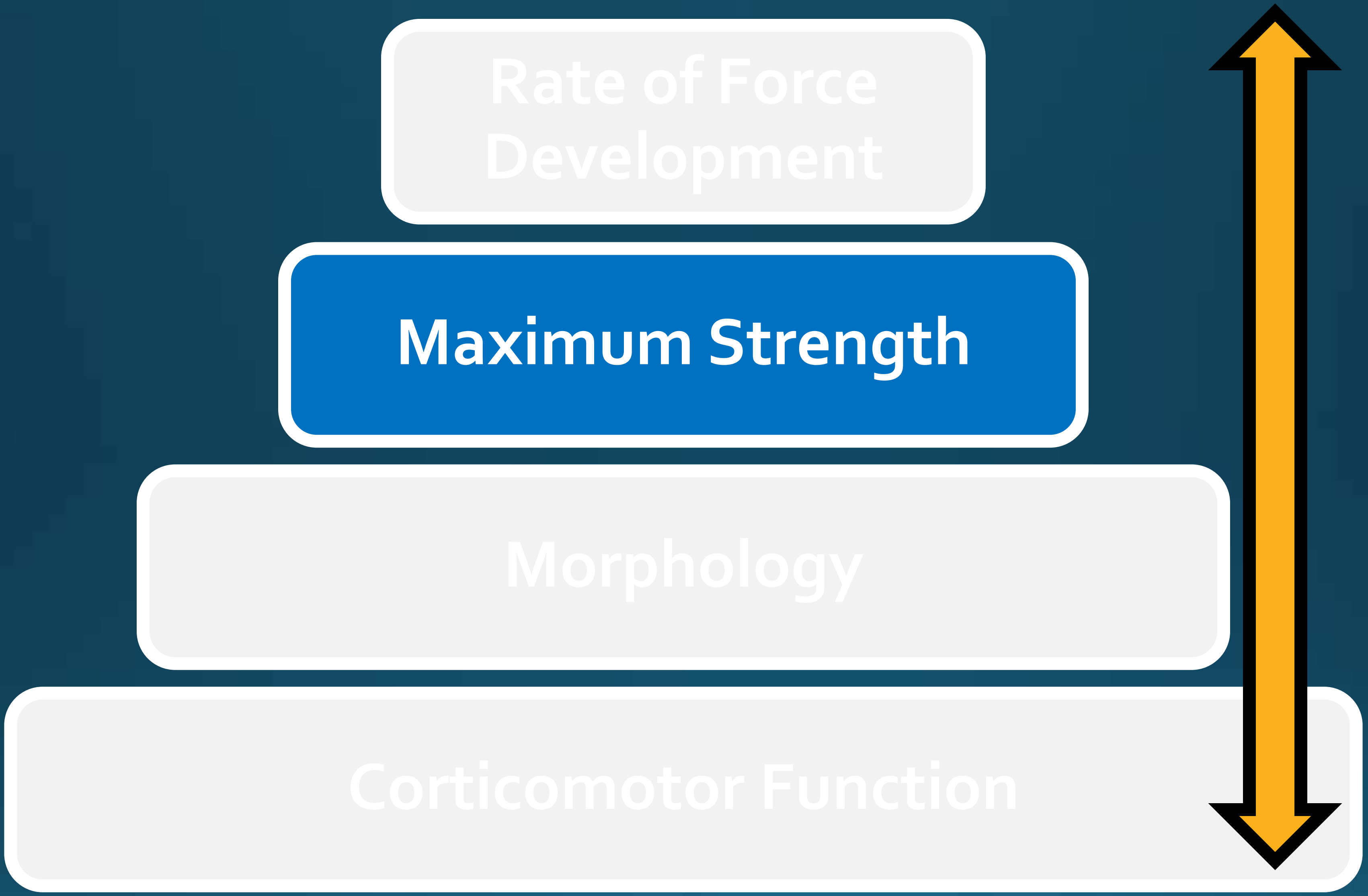
Maximum Strength

Morphology

Corticomotor Function



TWIN CITIES ORTHOPEDICS | TRAINING HAUS


Rate of Force Development
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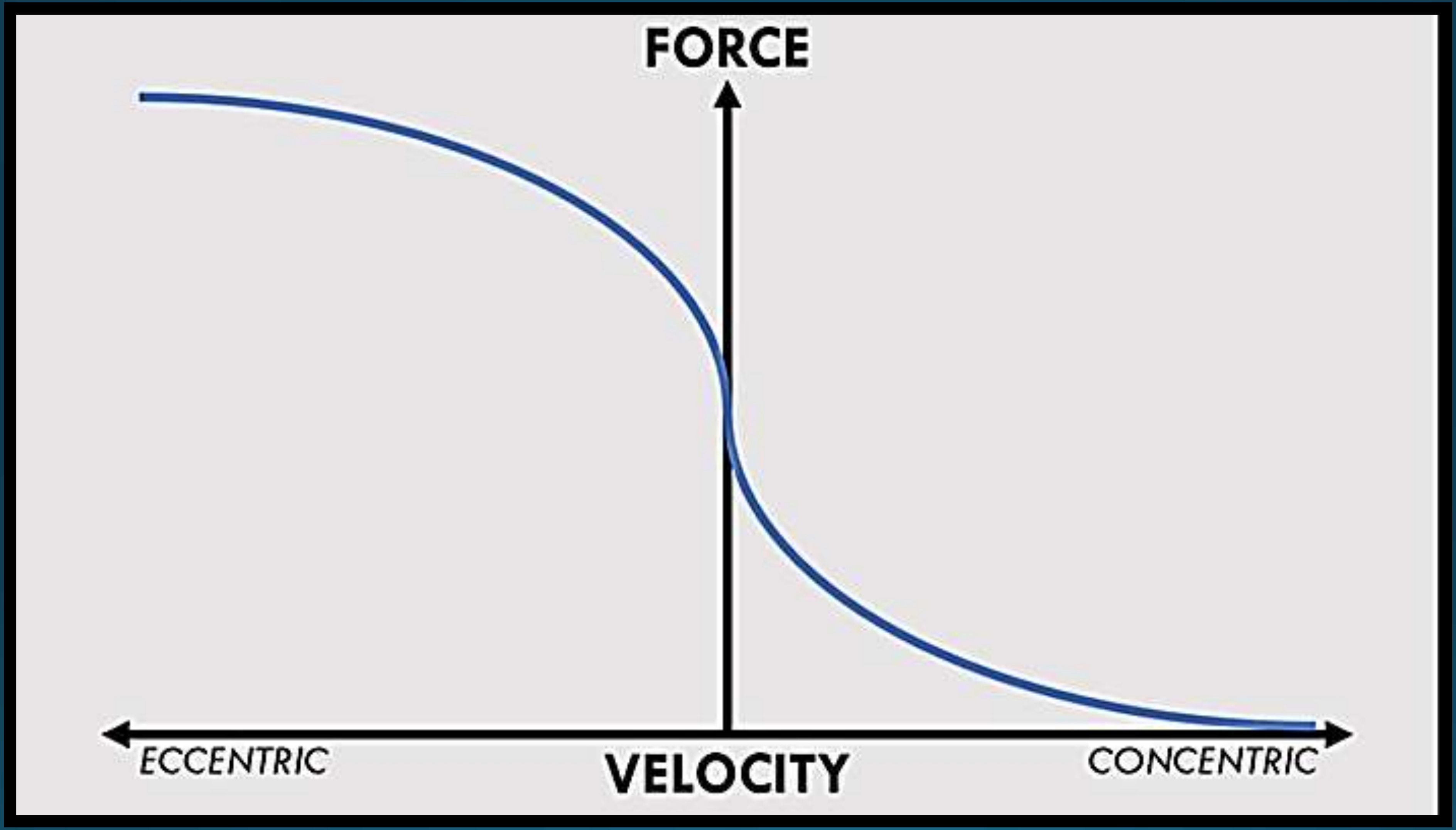
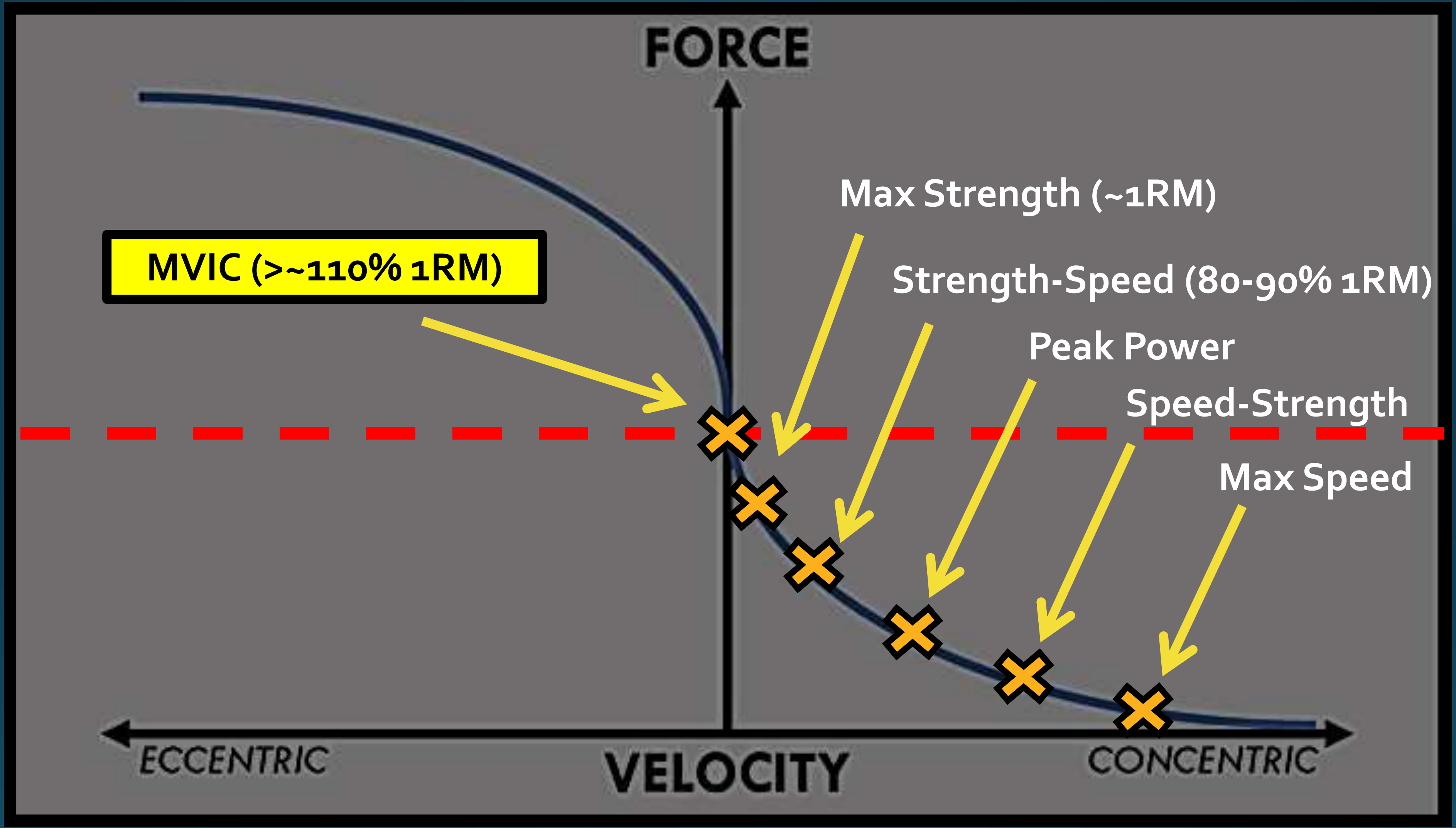
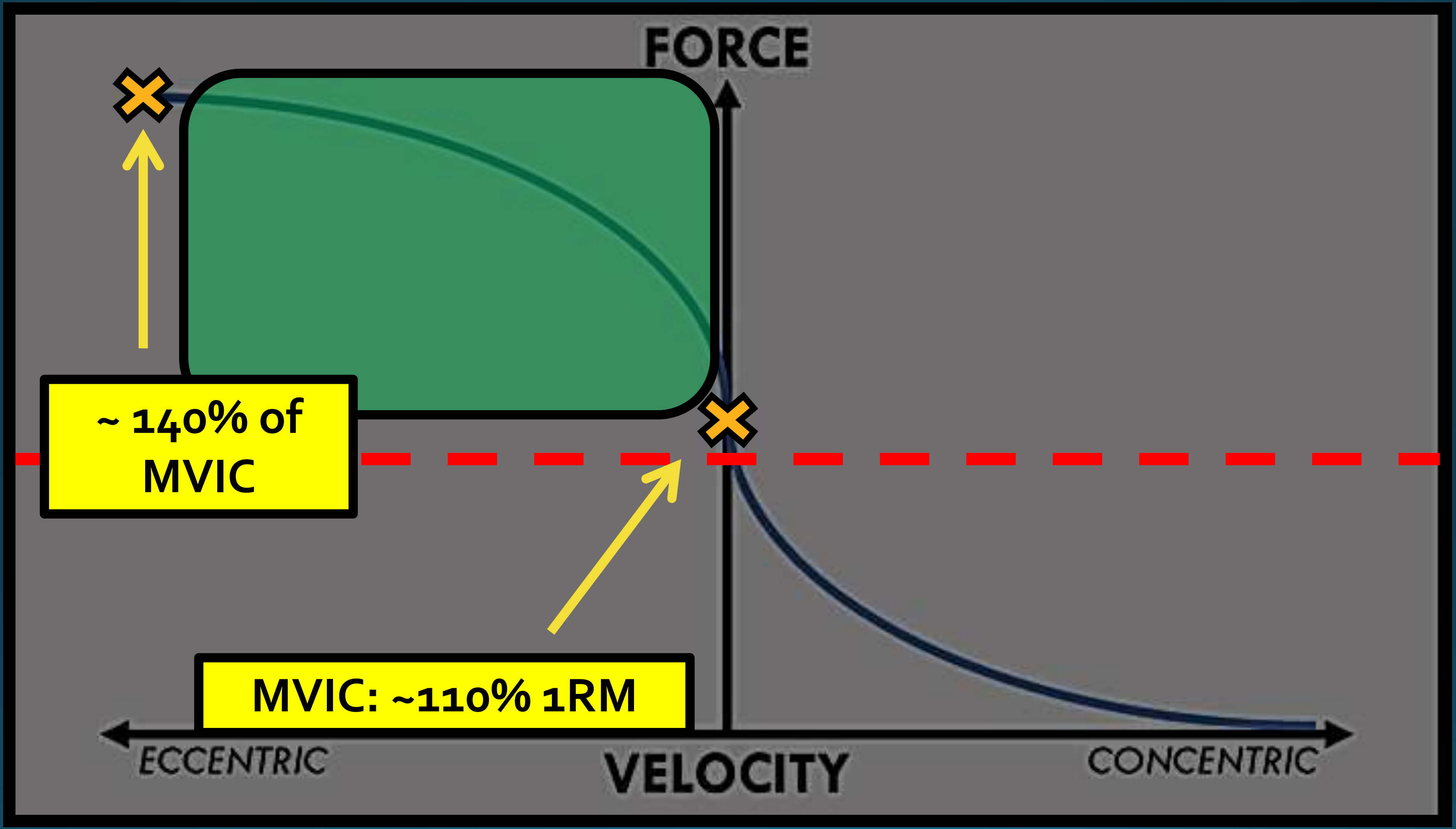
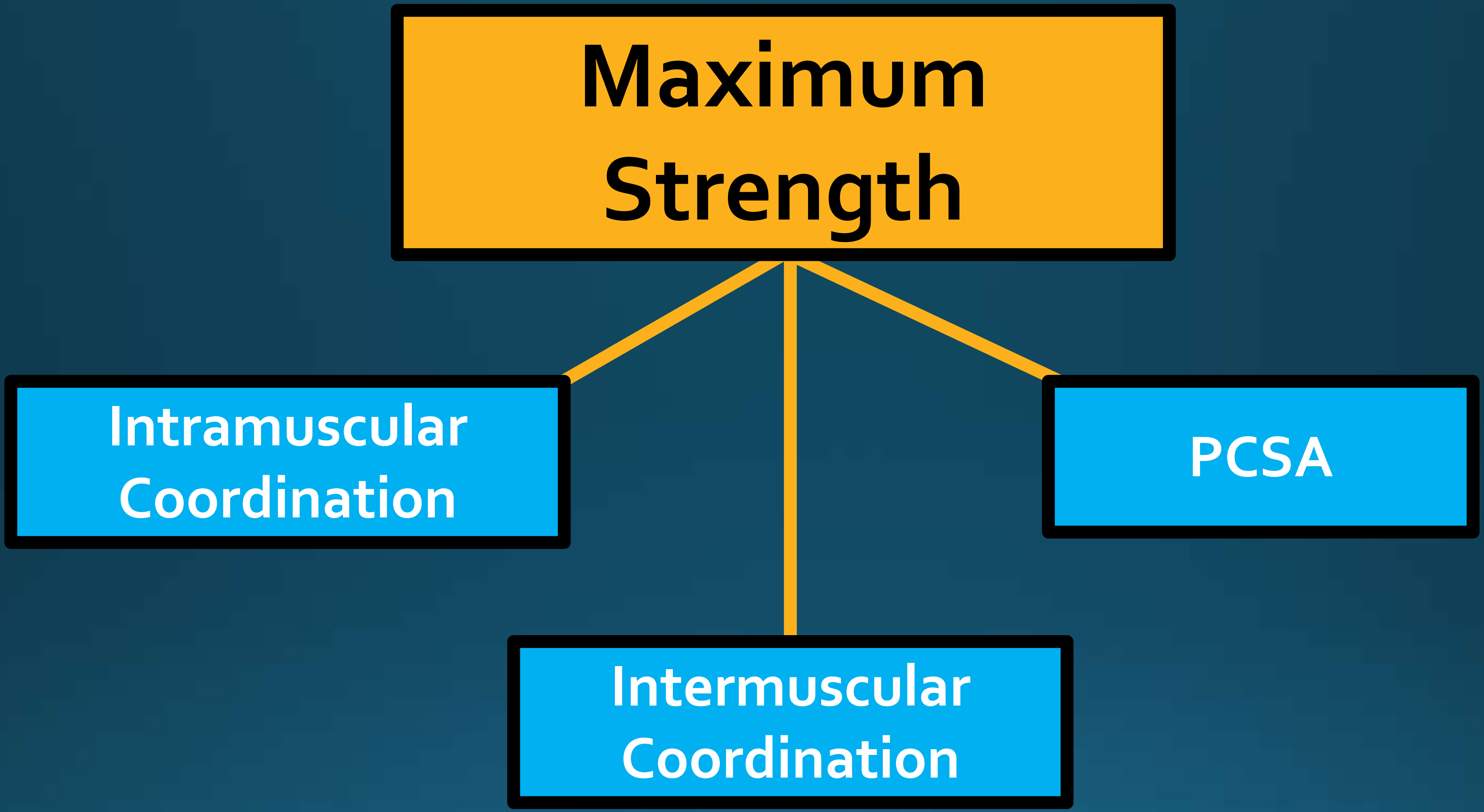

FORCE
ECCENTRIC
VELOCITY
CONCENTRIC


FORCE
MVIC (>~110% 1RM)
Max Strength (~1RM)
Strength-Speed (80-90% 1RM)
Peak Power
Speed-Strength
Max Speed
ECCENTRIC
VELOCITY
CONCENTRIC


FORCE
~ 140% of MVIC
MVIC: ~110% 1RM
ECCENTRIC
VELOCITY
CONCENTRIC



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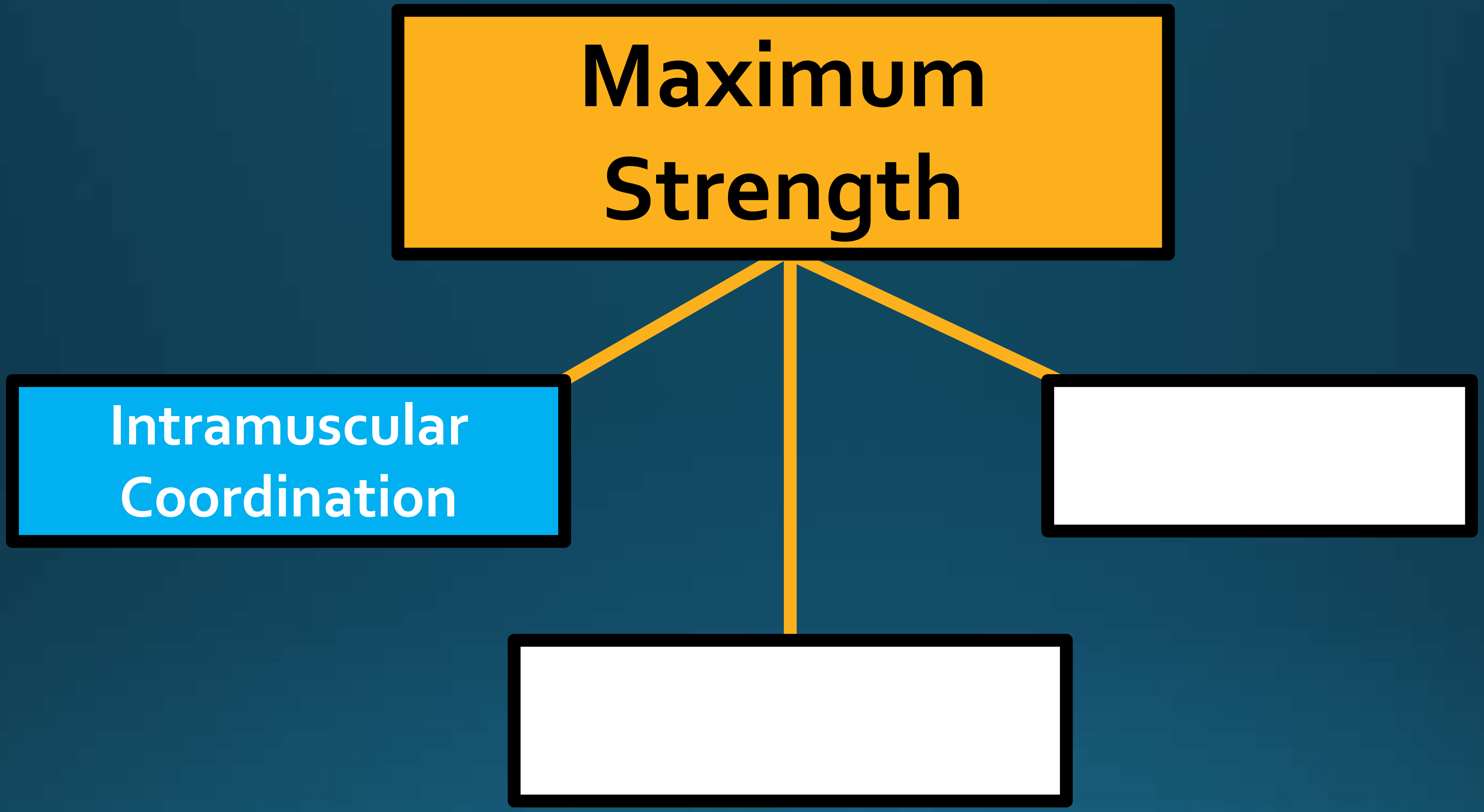

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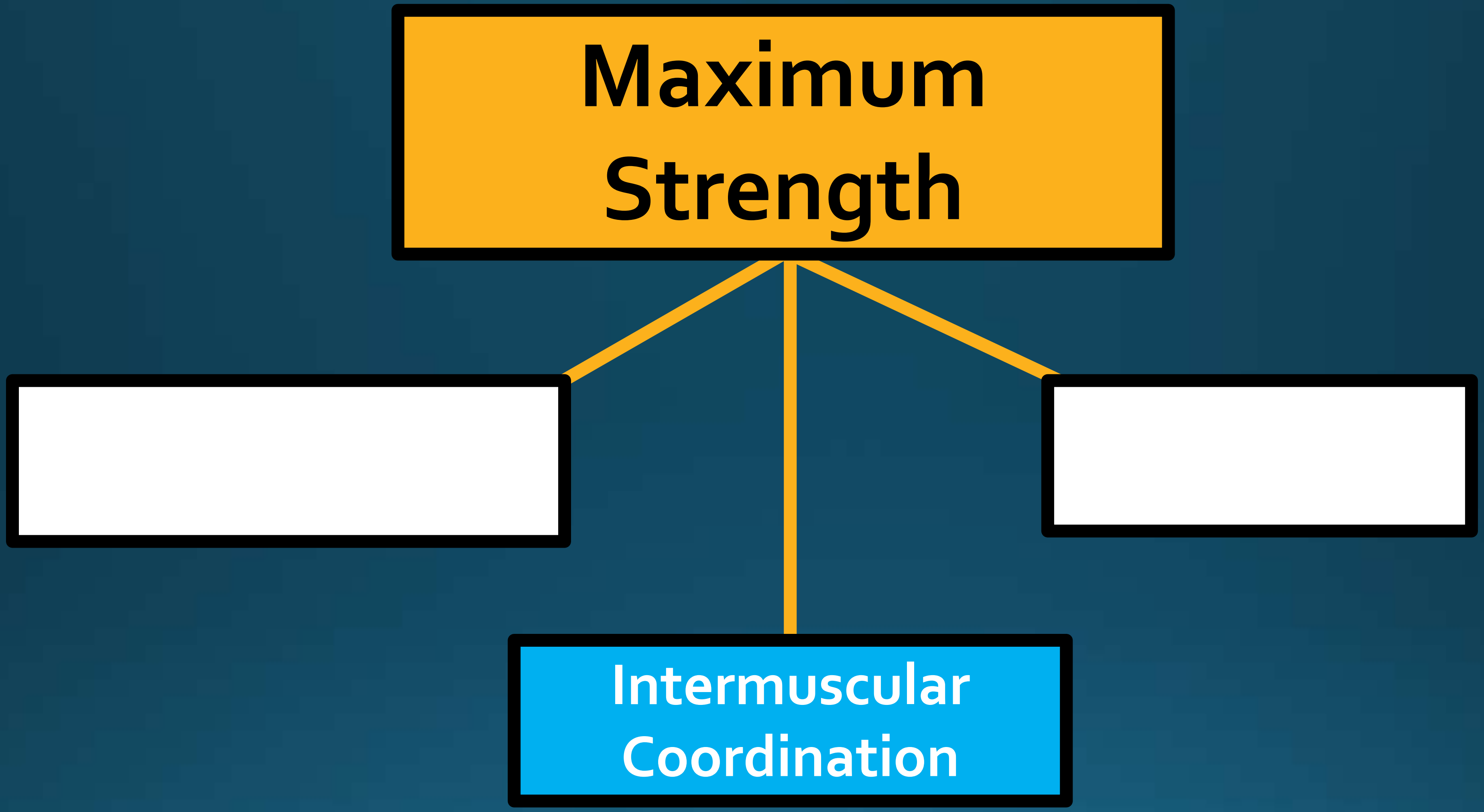

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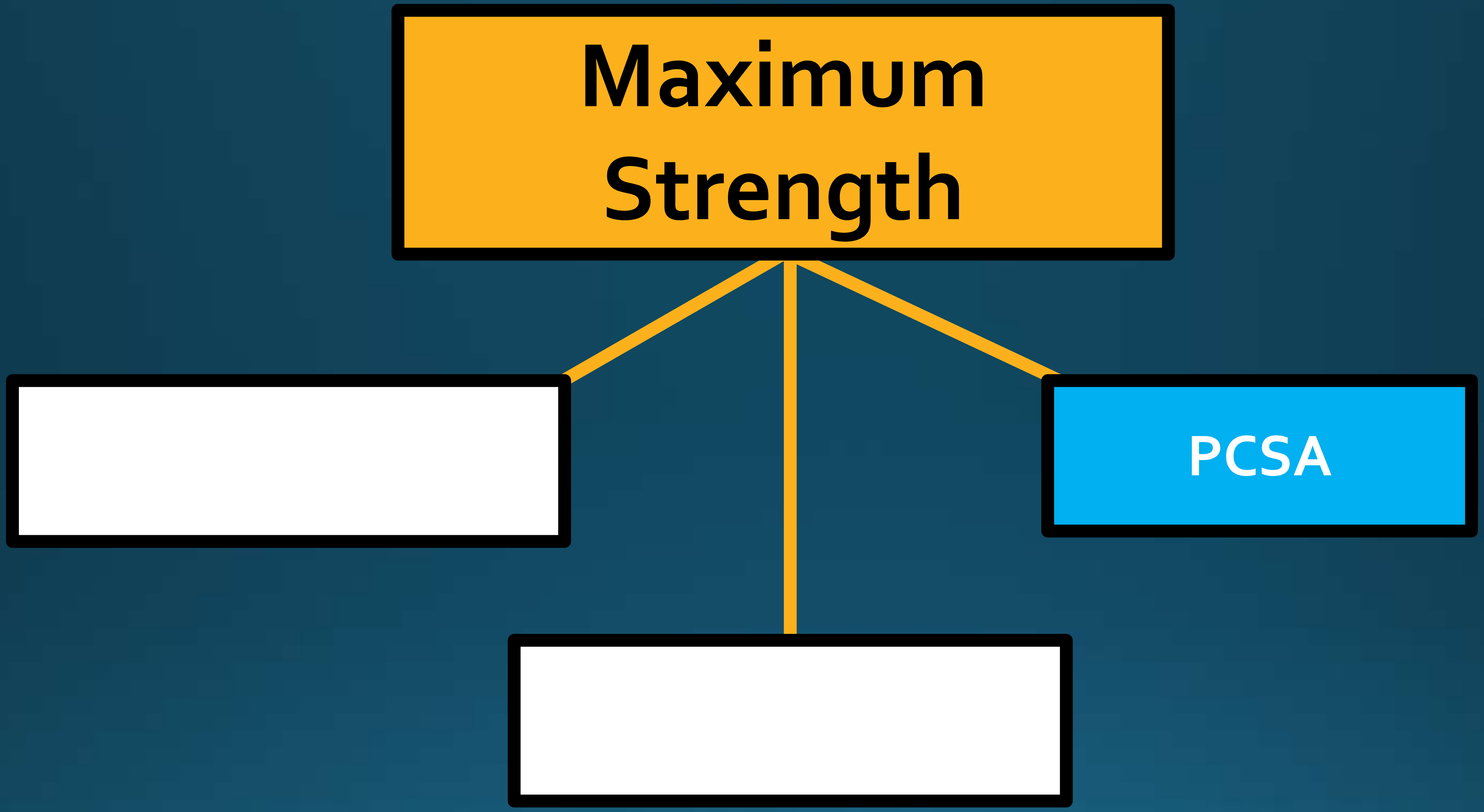

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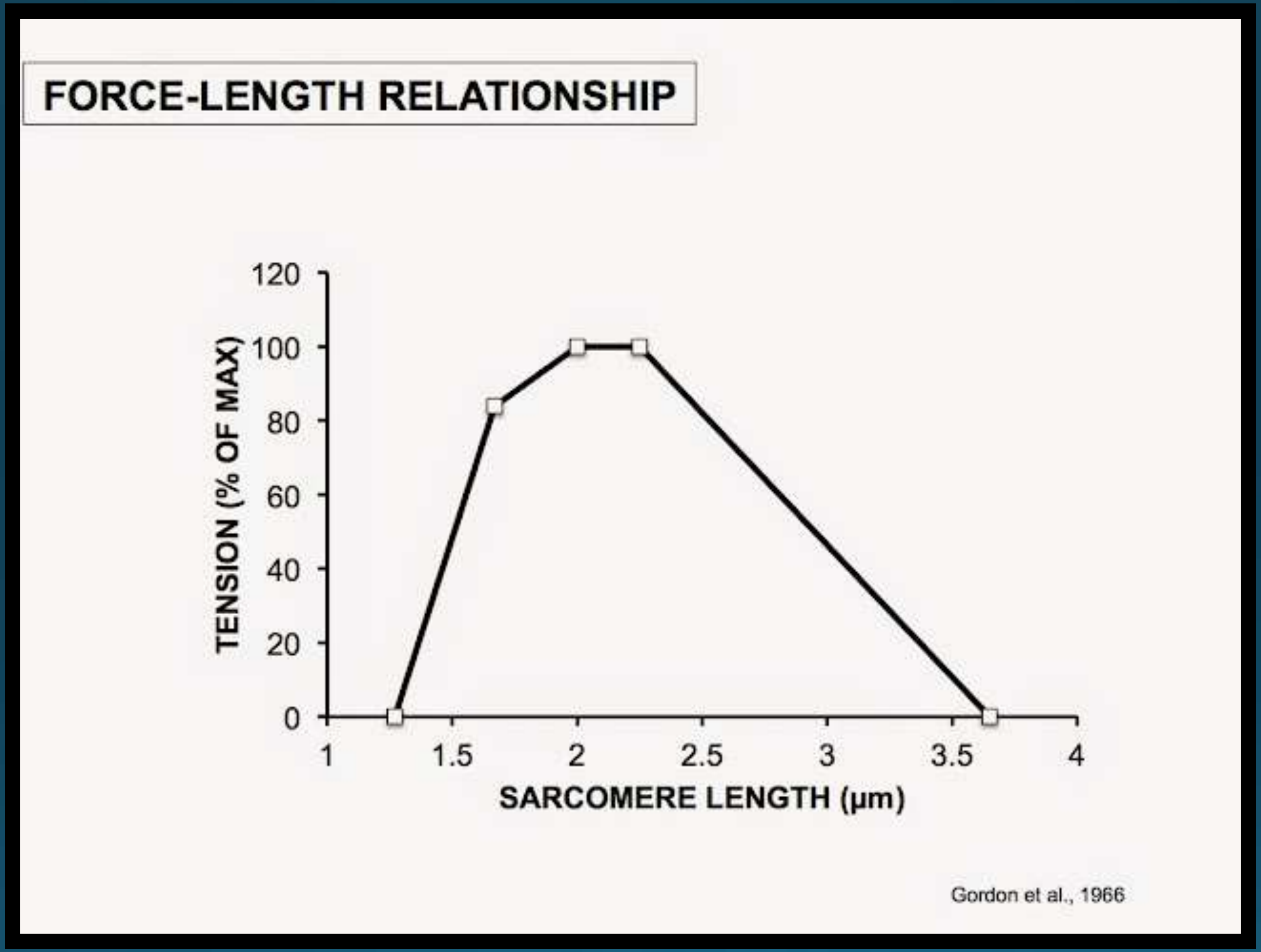

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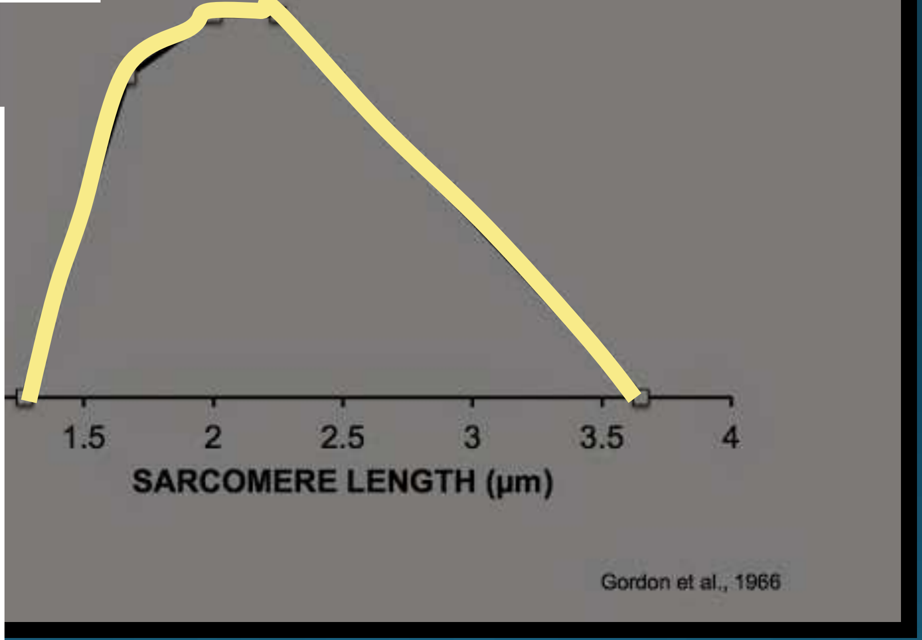

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Sports Med
https://doi.org/10.1007/s40279-018-0862-z

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REVIEW ARTICLE

The Importance of Muscular Strength: Tr ng Considerations

Timothy J. Suchomel[1] · Sophia Nimphius[2] · Christopher R. Bellon[3]
Michael H. Stone[4]

Table 2 The theoretical potential of resistanc ng methods to benefit hypertrophy, strength, and power

Resistance training method	Hypertrophy	Strength	Power
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Machine-based exercise	++	++	++
Weightlifting derivatives	+++	+++	+++++
Plyometrics	+	++	++++
Eccentric training	+++++	+++++	++++
Potentiation complexes	[a]	+++	+++++
Unilateral exercise	+++	++	+++
Bilateral exercise	[illegible]	[illegible]	[illegible]
Variable resistance	+++++	++++	++++
Kettlebell training	++	++	+++
Ballistic training	++	+++	+++++

Resistance training methods ranked on scale from +, meaning low potential and +++++, meaning high potential

Assigned exercises, volume-load prescription, and an athlete's relative strength may influence adaptations

[a]Limited research available

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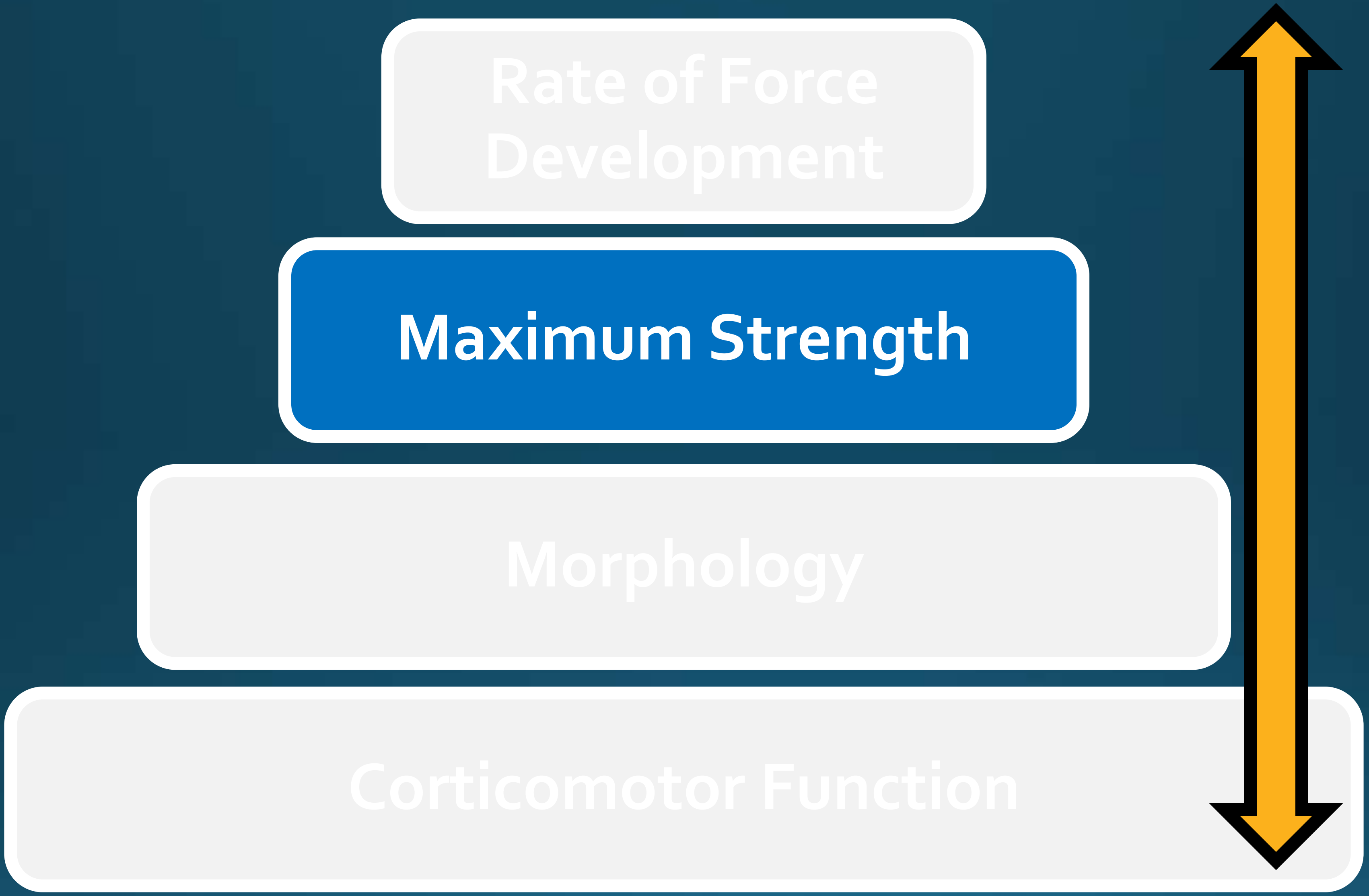
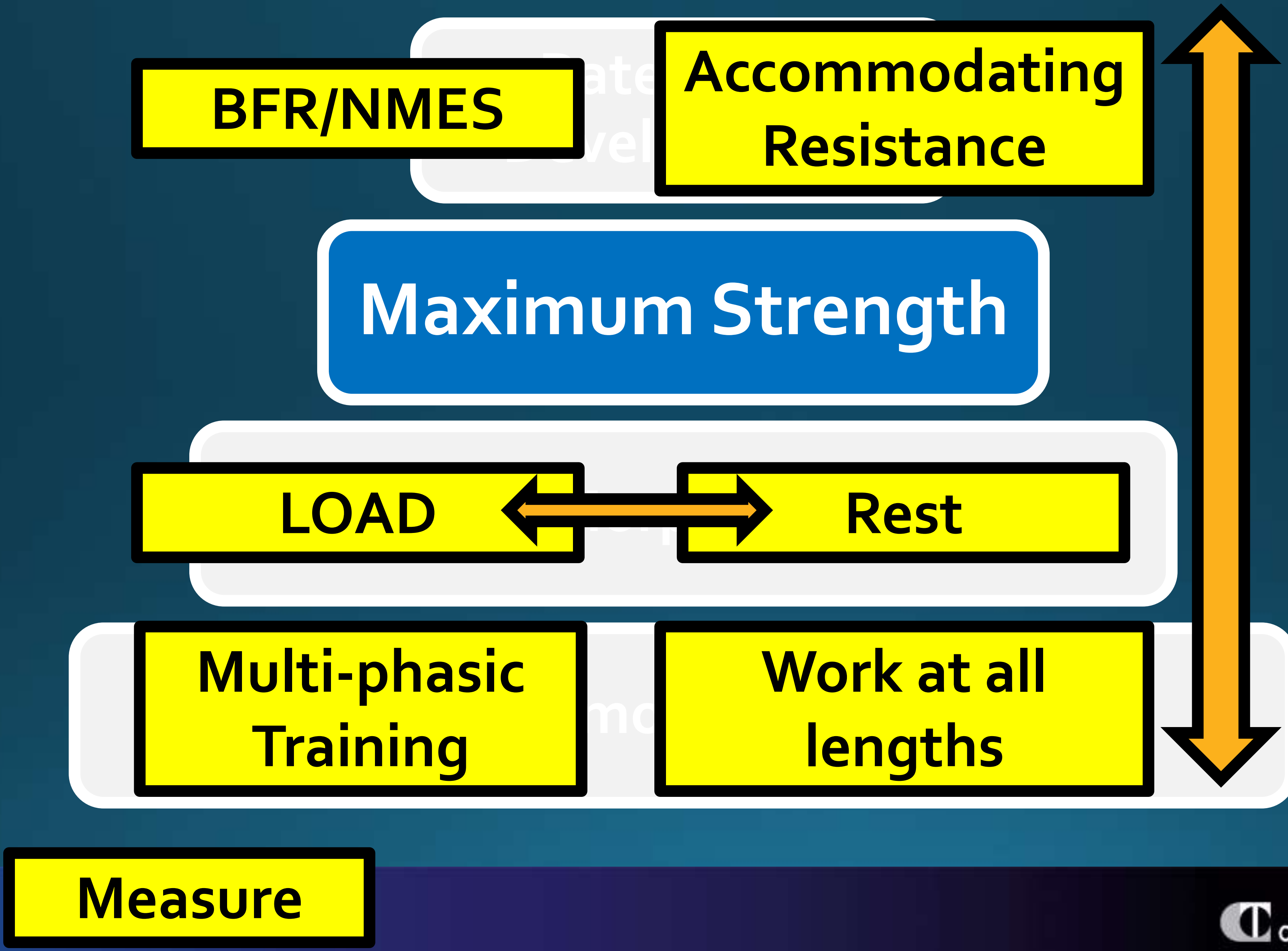
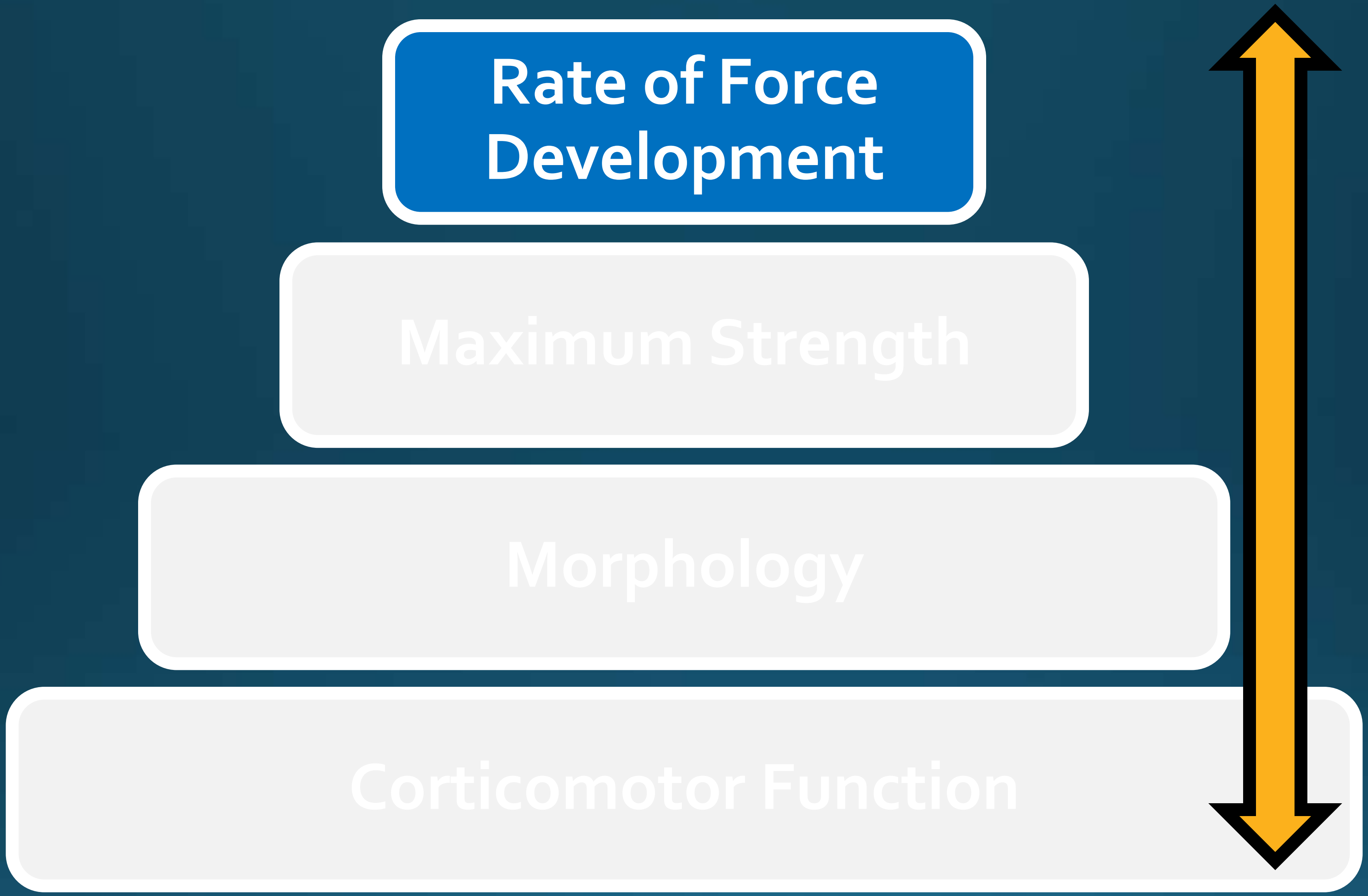

Rate of Force Development
Maximum Strength
Morphology
Corticomotor Function


BFR/NMES
Accommodating Resistance
Maximum Strength
LOAD
Rest
Multi-phasic Training
Work at all lengths
Measure


STARTED FROM THE BOTTOM
NOW WE HERE
imgflip.com



Rate of Force Development
Maximum Strength
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Developing Powerful Athletes, Part 1: Mechanical Underpinnings

Anthony N. Turner, PhD,[1] Paul Comfort, PhD,[2] John McMahon, PhD,[2] Chris Bishop, MSc,[1] Shyam Chavda, M
Paul Read, PhD,[3,4] Peter Mundy, PhD,[5] and Jason Lake, PhD[6]
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[4]Centre for Exercise and Sports Science Research, Edith Cowan University, Joondalup, Australia; [5]Coventry
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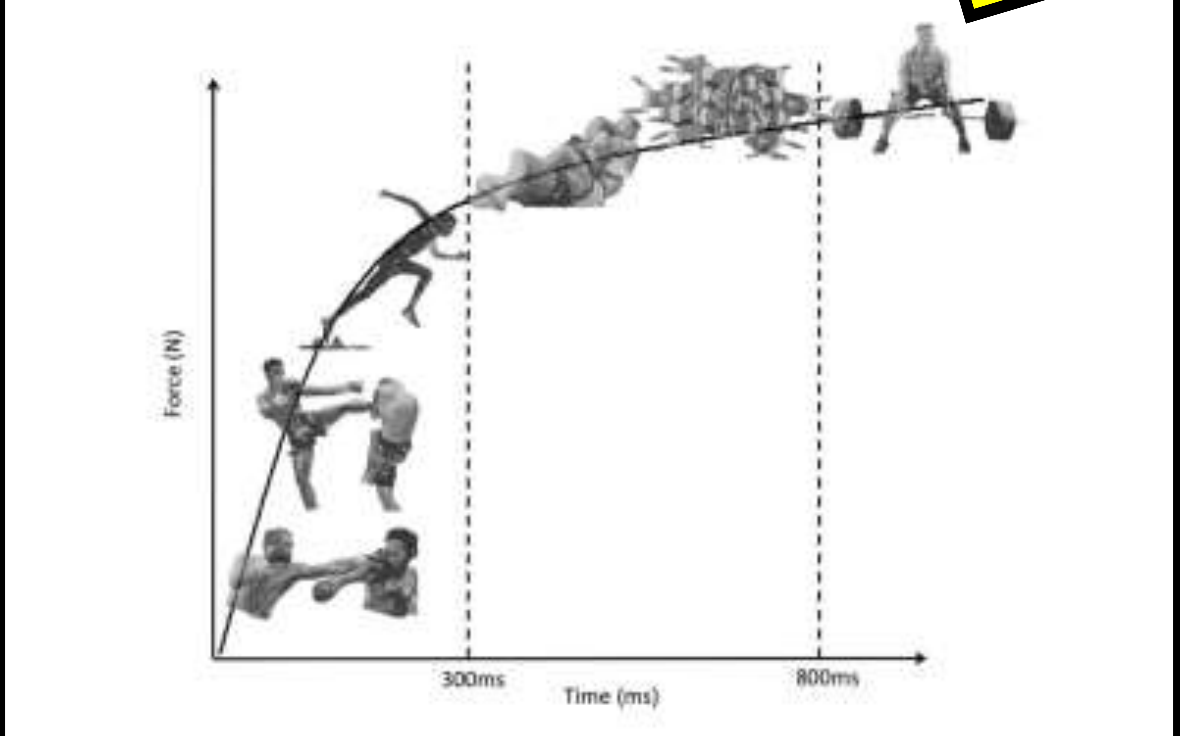

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[1]London Sports Institute, Middlesex University, Greenlands Lane, United Kingdom; [2]University of Salford, School of Health and Society, Salford, United Kingdom; [3]Aspetar Aspetar Orthopaedic and Sports Medicine Hospital, Doha, Qatar; [4]Centre for Exercise and Sports Science Research, Edith Cowan University, Joondalup, Australia; [5]Coventry University, Coventry, United Kingdom; and [6]Chichester Institute of Sport, University of Chichester, Chichester, United Kingdom

ACL Rupture
(<50 ms)

Hamstring strain
(50-100 ms)

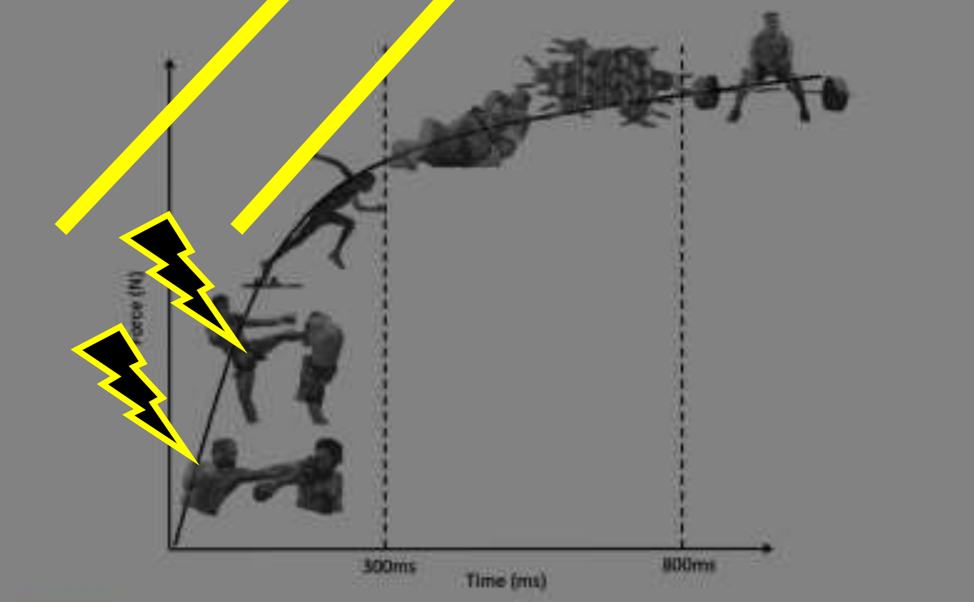
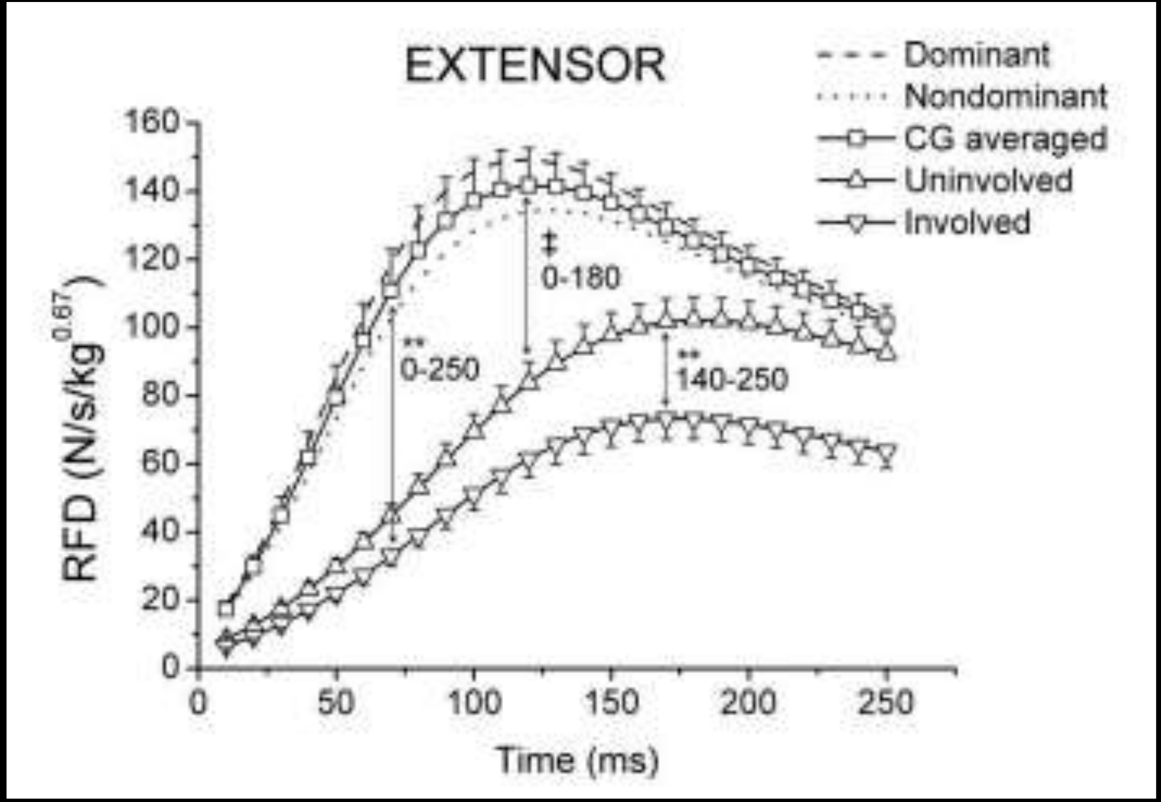


Figure 1. Force-time curve reveals that maximum force is not instantaneously developed, taking as much as 0.6–0.8 seconds to develop. The majority of athletic movements, however, occur within <0.3 seconds.

Contralateral limb deficit after ACL-reconstruction: an analysis of early and late phase of rate of force development

Dragan M. Mirkov[a], Olivera M. Knezevic[b], Nicola A. Maffiuletti[c], Marko Kadija[d], Aleksandar Nedeljkovic[a] and Slobodan Jaric[e]



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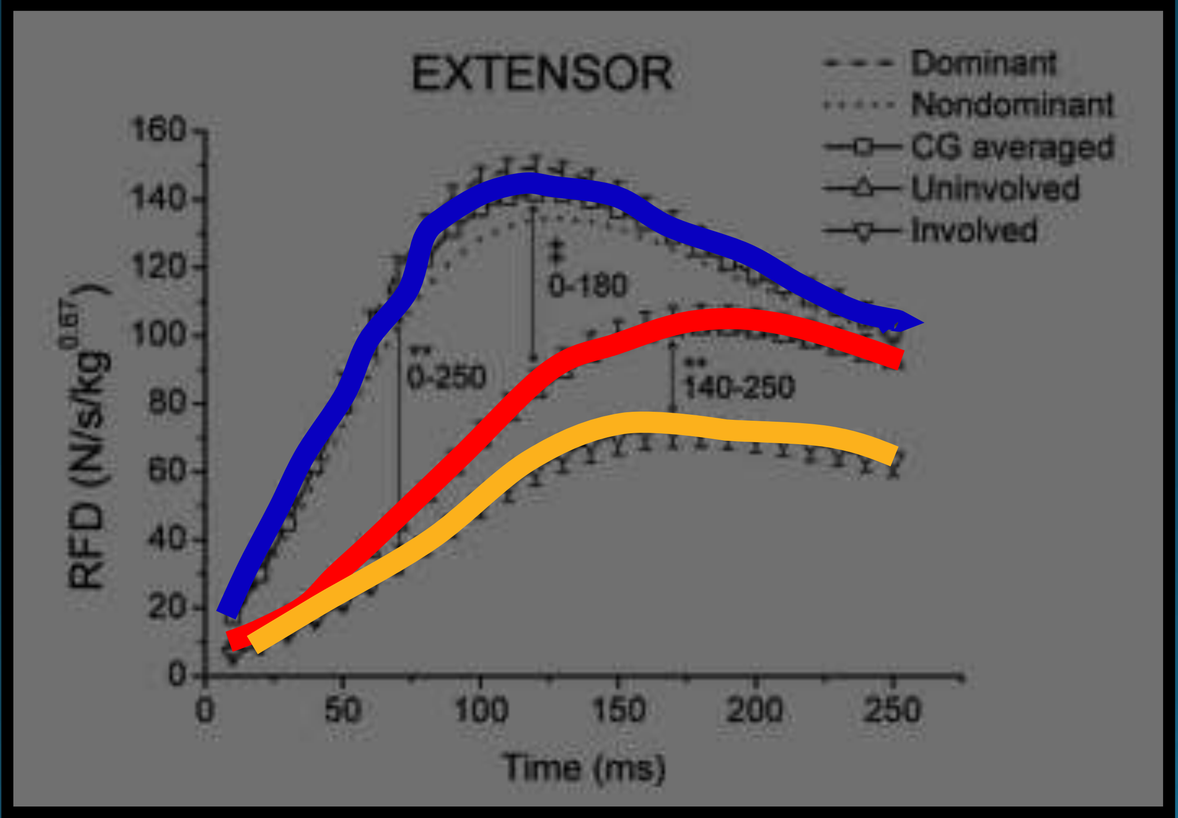

Control Group

Uninvolved

Involved

Eur J Appl Physiol (2016) 116:1091–1116
DOI 10.1007/s00421-016-3346-6

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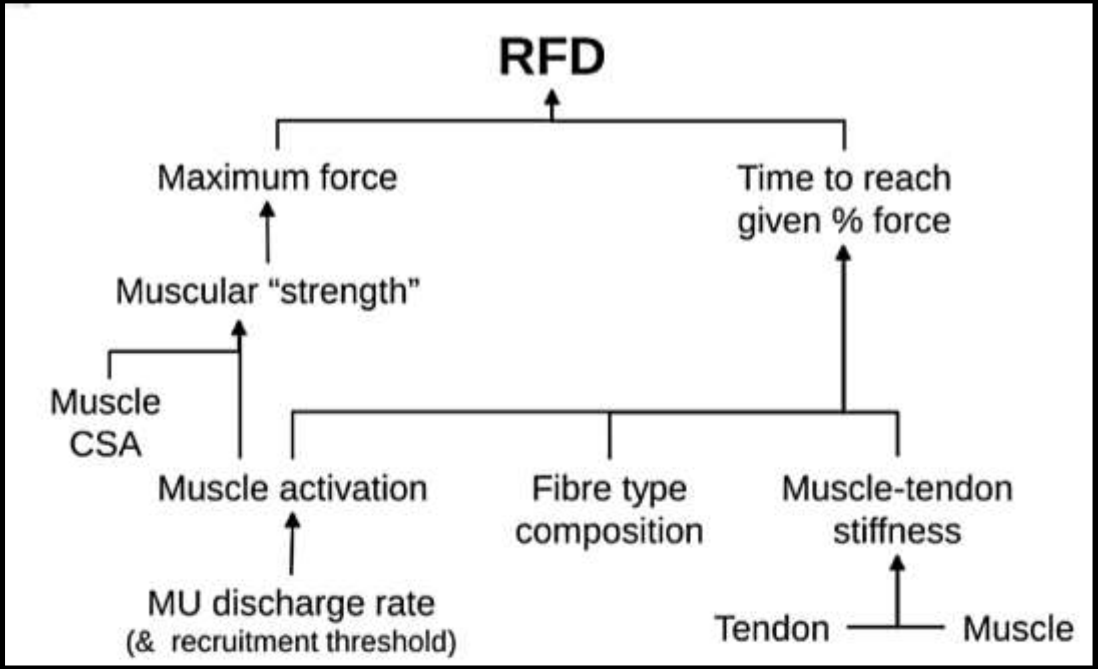
INVITED REVIEW

Rate of force development: physiological and methodological considerations

Nicola A. Maffiuletti[1] · Per Aagaard[2] · Anthony J. Blazevich[3] · Jonathan Folland[4] · Neale Tillin[5] · Jacques Duchateau[6]



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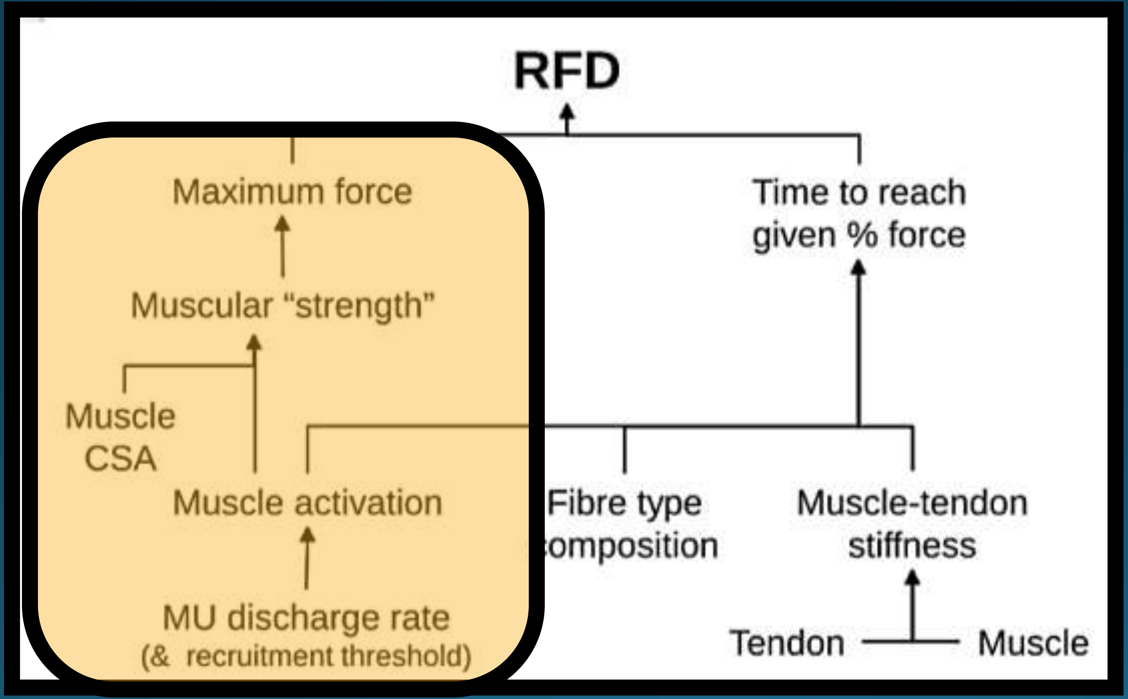

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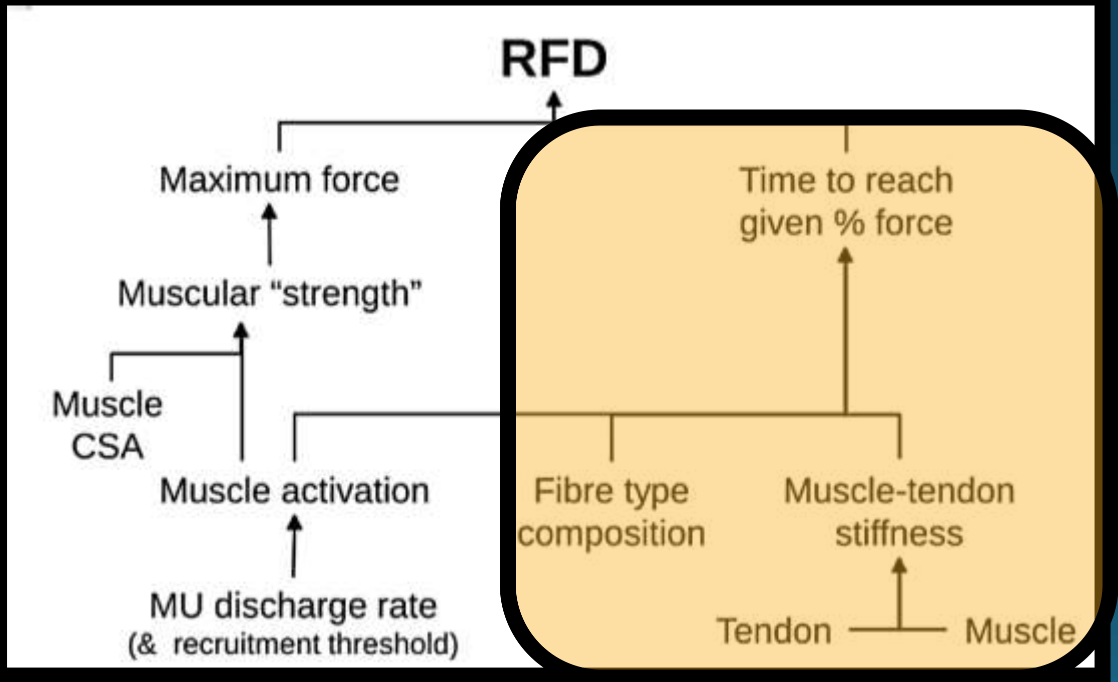
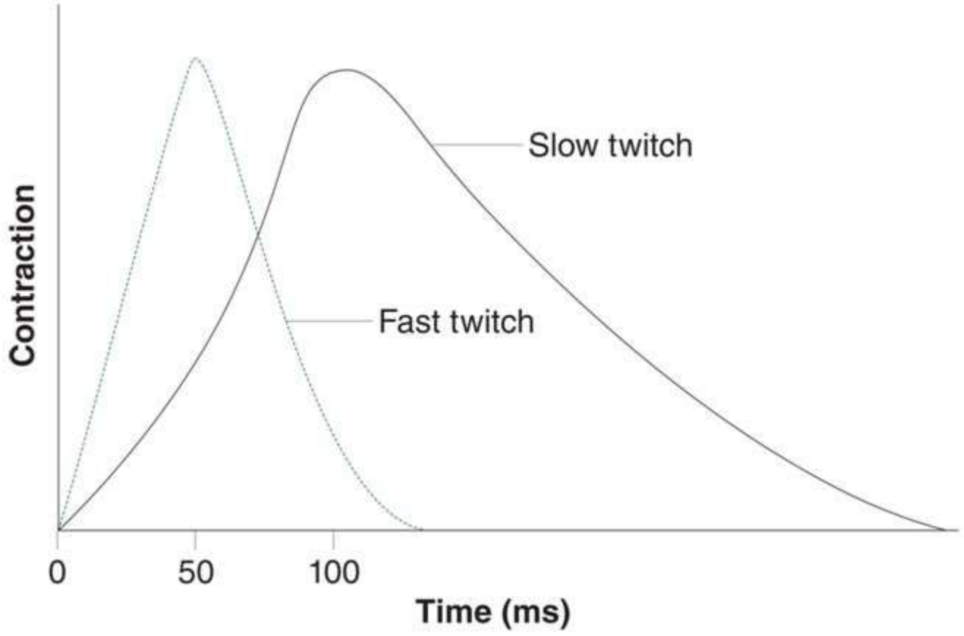


Type I vs. Type II Muscle Fiber Contraction Rates



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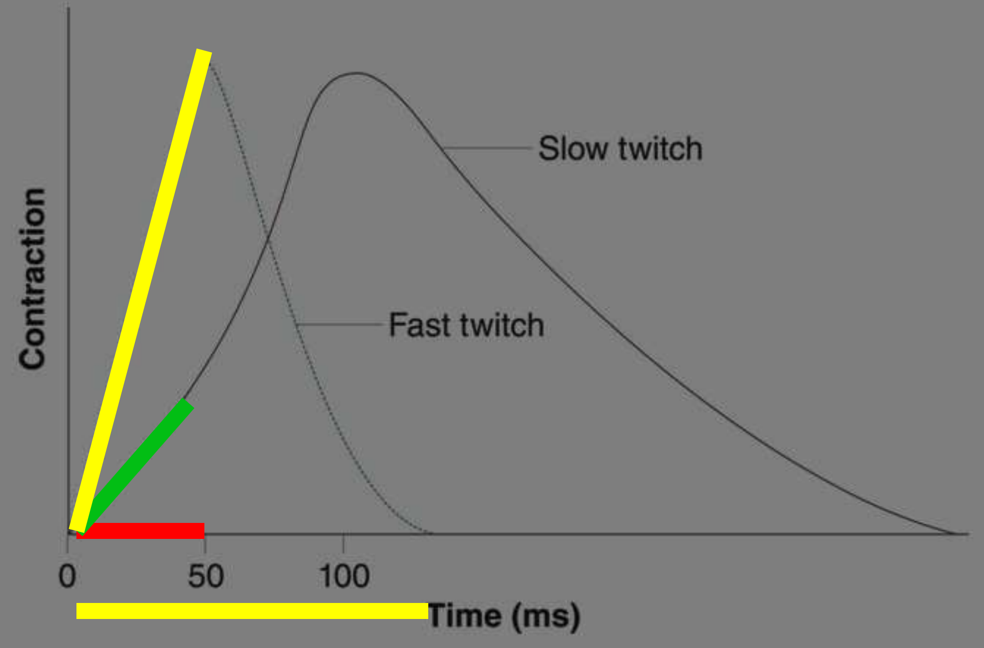

Sports Med
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REVIEW ARTICLE

The Importance of Muscular Strength: Training Co[illegible]erations

Timothy J. Suchomel[1] · Sophia Nimphius[2] · Christopher R. Bellon[3] ·
Michael H. Stone[4]

Table 2 The theoretical potential of resistance training m[illegible] to benefit hypertrophy, strength, and power

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Eccentric training	+++++	+++++	++++
Potentiation complexes	[a]	+++	+++++
Unilateral exercise	+++	++	+++
Bilateral exercise	++++	++++	+++
Variable resistance	+++++	++++	++++
Kettlebell training	++	++	+++
Ballistic training	++	+++	+++++

Resistance training methods ranked on scale from +, meaning low potential and +++++, meaning high potential

Assigned exercises, volume-load prescription, and an athlete's relative strength may influence adaptations

[a]Limited research available

TWIN CITIES ORTHOPEDICS
TRAINING HAUS

Table 1. Force and power characteristics of various exercises.

Exercise	Peak Power (W)	Peak Force (N)	RFD ($N \cdot s^{-1}$)
Power Clean	2,591[1]	2,264[1]	8.657[1]
Isometric Mid-Thigh Clean Pull	N/A	3,177[2]	22,008[2]
Hang Power Clean	3,183[1]	2,479[1]	10,314[1]
Mid-Thigh Power Clean	3,565[1]	2,813[1]	15,049[1]
Mid-Thigh Clean Pull	3,686[1]	2,901[1]	15,623[1]
Back Squat	2,637[2]	2,680[2]	5,083[2]
Deadlift	1,149[4]	2,954[4]	6,408[4]
Countermovement Jump	4,299[5]	1,836[5]	8,757[5]
Jump Squats	3,050[6]	2,892	Not reported

NOTE: The data within this table is based on lifts at 60% and 70% of 1RM and is compiled from several resources.

[1] Data extracted from (14): 60% of 1RM – Elite male rugby league players

[2] Data extracted from (11): 60% of 1RM – Elite male collegiate weightlifters

[3] Data extracted from (12): 70% of 1RM – Male powerlifters

[4] Data extracted from (13): 70% of 1RM – Male powerlifters and rugby union players

[5] Data extracted from (15): Unloaded – Trained male university students

[6] Data extracted from (16): 80% of 1RM – Athletically trained males

2-4X

Owen Walker. 1/29/2016. "What is the Force-Velocity Curve?"
https://www.scienceforsport.com/force-velocity-curve/

Review

Implementing Eccentric Resistance Training—Part 1: A Brief Review of Existing Methods

Timothy J. Suchomel [1,2,*], John P. Wagle [3], Jamie Douglas [4], Christopher B. Taber [5], Mellissa Harden [2,6], G. Gregory Haff [2,7] and Michael H. Stone [8]

Power Output

- ↑ Motor unit recruitment
- ↑ Activation of motor cortex
- ↑ Force production capacity
- ↑ Motor unit discharge rate
- ↑ MTU stiffness
- ↓ Regulation of inhibitory reflexes
- ↑ Muscle fascicle length
- Possible ↑ fast twitch motor unit preferential recruitment
- Possible ↑ type IIx fiber composition (phenotype shift)
- Possible ↑ excitation–contraction coupling rates
- ↑ Muscle fiber shortening velocity

Train:

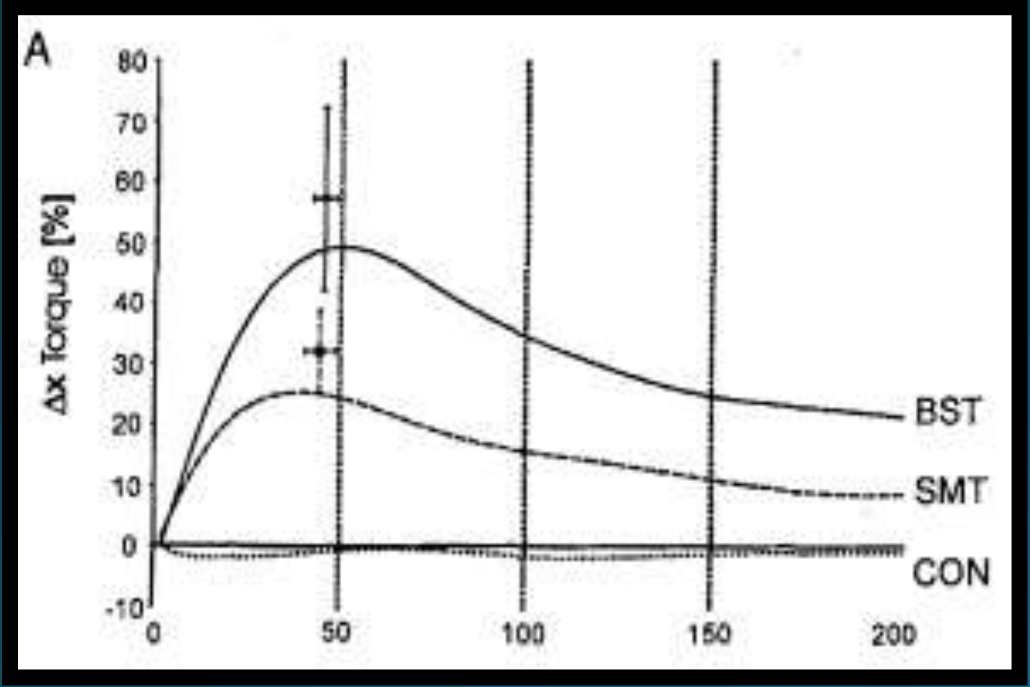
Slow

↓

Fast

Differential Effects of Ballistic Versus Sensorimotor Training on Rate of Force Development and Neural Activation in Humans

Markus Gruber,[1] Stefanie B.H. Gruber,[1] Wolfgang Taube,[1] Martin Schubert,[2] Sandra C. Beck,[2] and Albert Gollhofer[1]



4 wks of training:

↑ RFD

= Max Strength

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TRAINING HAUS

Table 4. *Energy System Training Parameters*

	Work Interval		Recovery		Series		Adaptation
	Intensity	*Duration*	*Intensity*	*Duration*	*Number of Series*	*Weekly Frequency*	*Timeframe*
Short Duration – Repeated Efforts							
Explosive Effort	Maximal	<6 s	Passive	30 to 120 s	2 to 6	2 to 3	2 to 3 weeks
High-Intensity Effort	Maximal	15 to 30 s	RPE <2	30 to 120 s	4 to 10	2 to 3	2 to 3 weeks
Endurance Effort	RPE 8 to 9	2-3 min	RPE <2	2-3 min	6 to 10	2 to 3	2 to 3 weeks
Long Duration – Endurance							
Extensive	Zone 1	20-60 min	Continuous			3 to 5	2 weeks to 3 months
Intensive	Zone 2 Zone 3	6-8 min 4-6 min	Low Zone 1	2-4 min	3 to 6	2 to 3	2+ weeks

Rate of Force Development

Maximum Strength

Morphology

Corticomotor Function

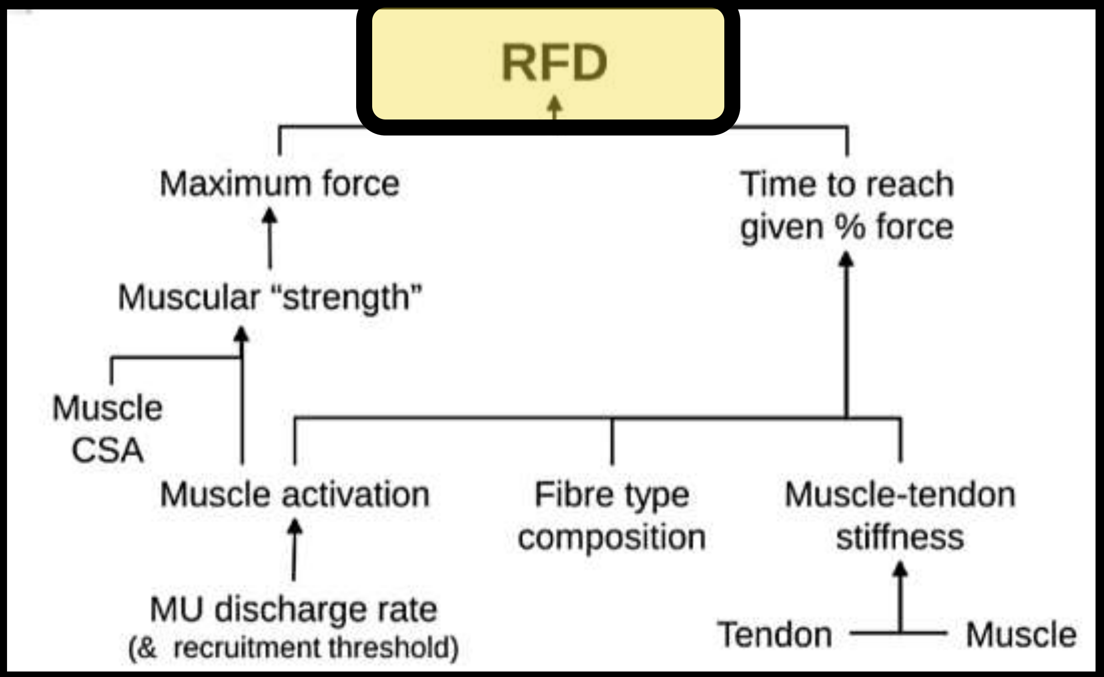
Eur J Appl Physiol (2016) 116:1091–1116
DOI 10.1007/s00421-016-3346-6

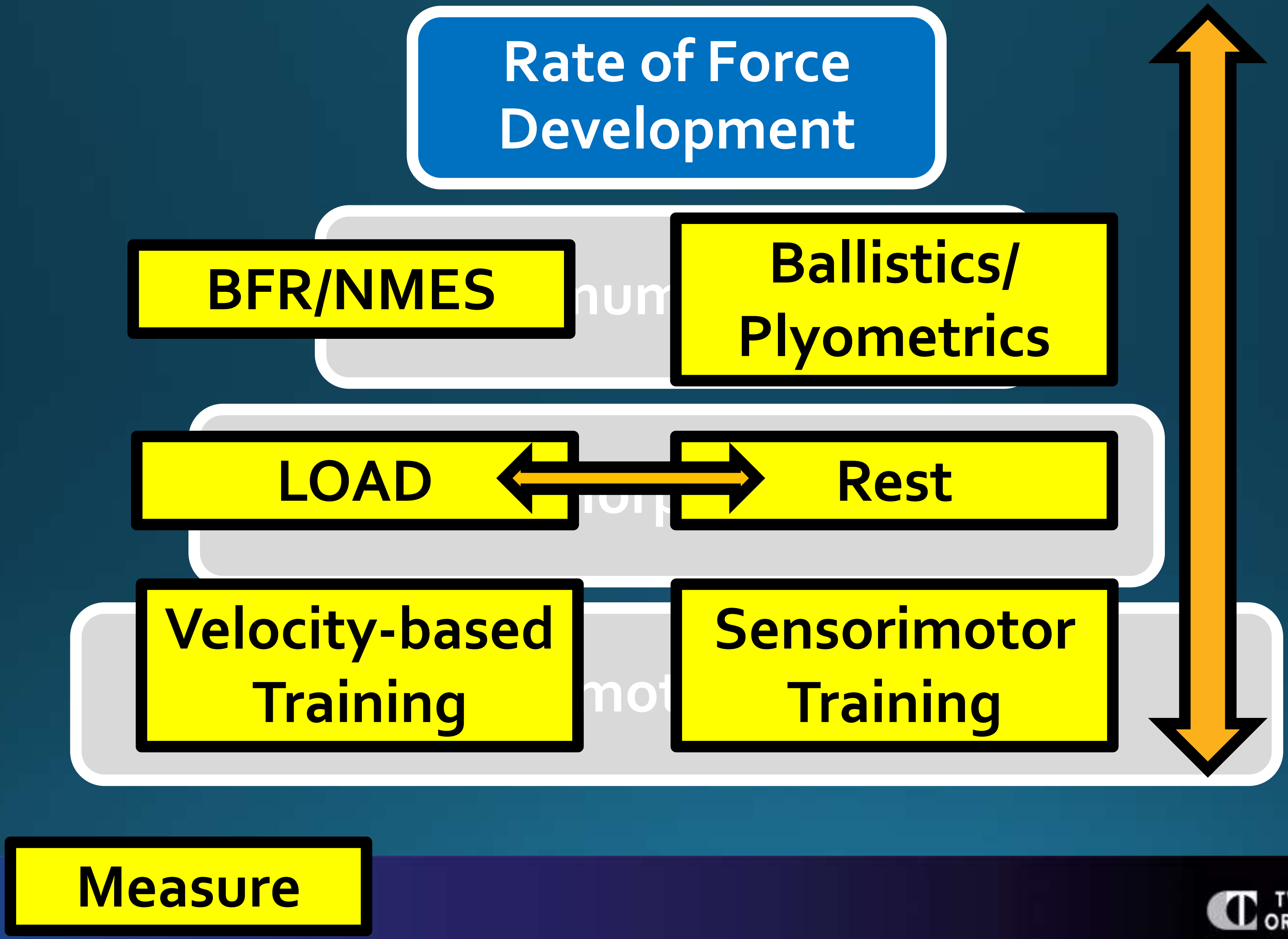
CrossMark

INVITED REVIEW

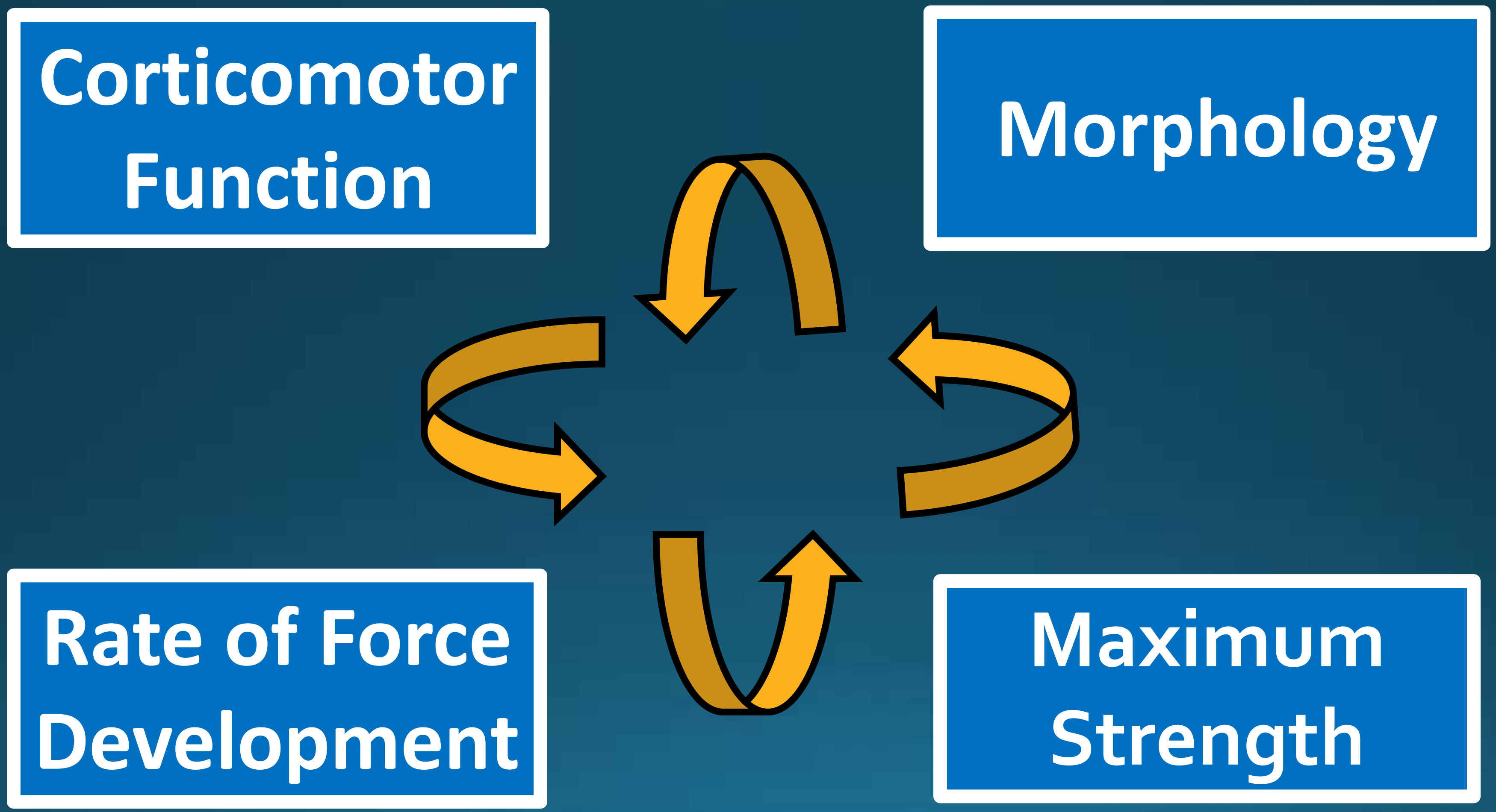
Rate of force development: physiological and methodological considerations

Nicola A. Maffiuletti[1] · Per Aagaard[2] · Anthony J. Blazevich[3] · Jonathan Folland[4] · Neale Tillin[5] · Jacques Duchateau[6]




Rate of Force Development
BFR/NMES
Ballistics/ Plyometrics
LOAD
Rest
Velocity-based Training
Sensorimotor Training
Measure

Food for thought:



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Thank You

Questions/Comments/Better memes?

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