Eccentric Training: Scientific and Practical Applications

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Schedule

- Effects of eccentric training
- Pathophysiology of tendinopathy
- Clinical intervention and demonstration
- Dosing, special considerations and cases

Objectives

- Recall evidence-based implications for incorporating eccentric training into clinical practice.
- Discuss the pathophysiology of painful tendinopathy.
- Examine clinical and basic science research related to eccentric loading for tendinopathy.
- Recognize appropriate eccentric exercise interventions.
Eccentric Training

• The lengthening of a muscle tendon unit while active, resulting in a negative movement, required under conditions of rapid deceleration; eccentric forces are required to reverse the body's trajectory after a particular athletic move–eg, jumping and throwing.

McGraw-Hill 2002
Dictionary of Medicine

NSCA Definition: Eccentric Action

• “……muscle lengthens because the contractile force is less than the resistive force. Forces generated within the muscle are less than external forces acting on it.”

Essentials of Strength and Conditioning, 2011

Case 1: Shoulder Pain

• 61-year-old male
• 1 year gradual onset, lateral shoulder pain
• Painful elevation
• Scapular dyskinesis
• GHJ mobility impairments
• Rotator cuff weakness
## Case 2: Knee Pain

- 36-year-old female
- 6 months anterior knee pain
- Running, squatting increase symptoms
- Dynamic valgus
- Impaired trunk control

## Supportive Evidence

- Clinical utility
- Risk factors & injury prevention
- Performance
  - Sport specific & functional applications
- Hormonal & growth factor response
- Hypertrophy
- Mechanotransduction
  - Muscle
  - Tendon

## Evidence for Clinical Prescription

- General conditions with “supporting” evidence
  - Shoulder impingement/tendinopathy/RTC tears
  - Lateral epicondylalgia
  - Bicep tendinopathy
  - Hamstring strains
  - Patellofemoral pain syndrome
  - Patellar tendinopathy
  - Achilles tendinopathy
  - Tibialis posterior tendinopathy
Outcome-Based Clinical Evidence

- **Patellar tendinosis**: Ecc vs. Conc
  - ↓ pain, ↑ satisfaction, ↑ sport return, ↓ future care
  - Johnson et al., Br J Sports Med, 2005

- **Achilles tendinosis**: Ecc vs. Conc
  - Premorbid activity return (82 vs 36%) & ↓ pain
  - Mufti et al., Knee Surg Sports Traumatol Arthrosc, 2001

- **Tibialis posterior tendinosis**: Case series
  - ↓ pain & disability, ↑ function & strength
  - Kulig et al., Foot Ankle Int, 2009

Outcome-Based Clinical Evidence

- **Lateral epicondylalgia**: Usual vs. Usual + Ecc
  - ↓ pain, ↑ strength, ↓ disability & US improvement

- **Shoulder impingement**: Case series
  - ↑ function & ↓ pain
  - Bernhardsson et al., Clin Rehabil, 2011

- **Shoulder impingement**: Usual vs. Usual + Ecc
  - ↑ function, ↓ pain, ↓ surgical decision (OR 7.7)
  - Holmgren et al., BMJ, 2012

Injury Risk & Prevention: Evidence

- **Sprinting athletes**: Previous hamstring injury
  - Eccentric hamstring weakness despite pain-free
  - Lee et al., Med Sci Sports Exerc, 2009

- **Elite sprinters**: Pre-season screening
  - Eccentric hamstring weakness predicted injury
  - Sugano et al., J Orthop Sports Phys Ther, 2008

- **Patellofemoral (PFPS): Patients vs. Controls**
  - PFPS associated with ↓ ecc hip abd/ER torque
  - Boling et al., J Athl Train, 2009

- **Soccer players**: Ecc hamstrings vs. Control
  - Ecc training ↓ rate of new and recurrent injury
  - Peterson et al., AM J Sports Med, 2011

- **Volleyball players**: Injured vs Non-Injured
  - Prev. injured shoulder associated w/ecc ER weakness
Specificity: Sport Performance

- **Patellar tendon**: Ecc superior to Con

- **Throwing sports**: Ecc ER key for deceleration

- Single-leg triple long jump & timed 6-m single-leg hop **scores related to Ecc strength**
  - Baldon et al, J Sport Rehabil, 2012

- **Eccentric training vs. traditional**
  - ↑ jump power, bench press & squat
  - Cook et al, J Strength Cond Res, 2012 (e-pub)

Specificity: Eccentric Needs for Gait

**Contractile Stiffness**

- Eccentric training may ↑ **contractile stiffness**

- **Implications:**
  - Stretch shortening cycle
    - ↑ power output & force production from stored energy via Series elastic component
  - Range of motion
    - No detrimental effect at lower extremity
    - Shoulder: Acute & chronic loss of IR mobility
    - Elbow: acute loss of elbow extension

Hypertrophy

- External rotators: Acute \(\uparrow\) cross-sectional area
  Goyama et al, Clin Biomech, 2011
- 5-week quadriceps strengthening: Ecc vs Conc
  \(\rightarrow\) Ecc \(\uparrow\) 2-fold \(\uparrow\) xs area than Conc
- Single bout of Ecc training: \(\uparrow\) satellite cells
  Dreyer et al, Muscle & Nerve, 2006
- Elbow flexor xs area (all fiber types): Ecc \(>\) Conc
- 20 days Ecc (in vivo): \(\uparrow\) xs area & \(\downarrow\) myostatin
  Ochi et al, J Strength Cond Res, 2011

What is Myostatin?

- Growth differentiation factor
- Inhibited by overload training & supplements

Hormonal & Growth Factor Responses

- \(\downarrow\) Myostatin & \(\uparrow\) IGF-MGF in muscle: Ecc \(>\) Conc
  Hommeri et al, J Appl Physiol, 2007
- 20 days training (in vivo): \(\uparrow\) xs area & \(\downarrow\) myostatin
  Ochi et al, J Strength Cond Res, 2011
- GH response of Ecc@ 90% 1RM \(>\) 70% 1RM
  Ojasto et al, J Strength Cond Res, 2009
- Ecc training (> 1 bout): \(\downarrow\) myostatin & \(\uparrow\) myogenin
- Ecc training: \(\uparrow\) MGF mRNA found on biopsy
- Conc vs Ecc: \(\uparrow\) IGF mRNA
  Bamman et al, Am J Physiol Endocrinol Metab, 2001
Mechanotransduction

- Process whereby body converts “mechanical” loading into a cellular response.
  - Cellular response = Change
  - Change = Upregulation of cellular DNA
    - Protein synthesis
    - Autocrine expression of IGF & MGF
  - Key attribute = “Overload”
    - Eccentric training


Mechanotransduction

- ↑ rate of collagen synthesis: Achilles tendinosis
- Achilles tendinosis: resembled normal tendon (3.8 yr)
- Lat. Epicondylalgia: Ecc vs Control
- Homogenous appearance w/ ↓ thickness in Ecc group
- ↑ satellite cell per fiber w/ eccentric training
  - Dreyer et al, Muscle Nerve, 2006
- ↓ intratendinous signal w/Ecc (3 mo & 4.2yr)
  - Gardin et al, Skeletal Radiol, 2010

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Summary: Eccentric Training

- Clinical utility
- Hypertrophy/Atrophy
- Preventative benefit among athletes
- Eccentric weakness: risk factor for injury
- Functional & Biomechanical
- Sport-specific
- Corrective: Tendinosis & Potentially muscle

Tendinopathy

Pathophysiology and Clinical Presentation

Proposed Model

Cook 2009

- Tendon pathology is likely a continuum
Reactive stage

- Tendon thickening
- Proliferation
- Protective
Tendon Disrepair

- An attempt at tendon healing
- Matrix breakdown
  - Chondrocytic
  - Increased protein production
  - Vascularity changes
  - Neuronal ingrowth

- Collagen becomes separated and disorganized

Neovascularization

Sharma 2006
Disrepair

Degenerative Tendinopathy

- Cell death, apoptosis
- Matrix destruction
- Likely irreversible and commonly leads to tendon tears
What factors contribute to tendon failure?

### Causative Mechanisms

- Chronic overload
  - Tensile
    - Overload with tissue breakdown
  - Shear, compression
- Unloaded tissue

### Characteristics

- Not necessarily age dependent  
  Cook 2000
- Risk Factors:
  - Adiposity  
    BMI >30  
    Gaida 2009
  - Metabolic alterations – dislipidemia
  - Diabetes  
    Holmes 2006
  - Genetic  
    Mokone 2005
Can these tissues heal?

- Extrinsic / Intrinsic
  - Kaux 2012
  - De Vos 2012
  - Knobloch 2007
- Other Interventions

Eccentric Intervention Prescription

- Patient/client selection
- Dosage
  - Load, intensity, volume, & frequency
- Specific dosage strategies
- Specific exercises
  - Lower quarter
  - Upper quarter

Eccentric Prescription

- Single most important factor for prescription?
- Frequency:____________________________
  - Evidence vs. Individual patient considerations
- Load: variable……………suggest:_____________
- Intensity criteria: Sports Med. vs. Rehabilitation
  - Strain vs. pain
  - D.O.M.S.
  - Repeated bout effect
**Eccentric Prescription Strategies**

- **Isolated training:**
  - Eccentric only (progression = ↑ reps & load)
  - Resisted eccentric w/assisted concentric throughout
  - Repetitions: 3 sets of 6-15

- **Combined within or at end of concentric set**
  - 2 up & 1 down or 1 down & 2 up
  - Concentric f/b extra eccentric reps
  - Contralateral to assist concentric at end of set
  - Positional length-tension/lever modification
  - Short concentric: Long eccentric

**Lower Quarter Eccentric Exercises**

- Achilles tendon/triceps surae
- Tibialis posterior
- Patellar tendon/quadriceps
- Hamstring muscle/tendons
- Hip: Abductors/external rotator
- General lower quarter

**Achilles Tendon/Tricep Surae**

  - N=26  mean age 50
  - Painful-chronic tendinosis
  - Ultrasound diagnosis & follow up
  - Rx = BID Heel drops 6* x 15
  - 7x week for 12-weeks
  - Work through pain
  - Results:
    - Tendon structure normal in 19/26 (3.8 yr follow-up)
    - 22/26 satisfied with treatment
Triceps Surae/Achilles Tendon

Calf raises (2-up:1-down) w/ progressively ↑ dorsiflexion range

Triceps Surae/Achilles Tendon

Total Gym: 2 up-1 down

Total Gym: w/t-band

Tibialis Posterior

• Kulig et al, *Foot Ankle Int.*, 2009
  ➢ N=10  mean age 52
  ➢ Painful-tibialis posterior tendinopathy
  ➢ Ultrasound diagnosis & follow up
  ➢ Rx = Ecc PF/adduction + stretch + orthosis
  ➢ 3x15 – BID – 7x week for 10-weeks
  ➢ Results:
    ➢ ↓ pain & disability, ↑ function & strength
    ➢ No change in tendon morphology
Patellar Tendon/Quadriceps

  - N=19  mean age 25
  - Patellar tendinopathy
  - Ultrasound diagnosis
  - RCT: Eccentric vs. Concentric
  - Rx = BID Decline squats (slant board)
    - 3x15: 7x week for 12-weeks w/ pain
  - Results:
    - ↓ pain & ↑ VISA in eccentric group
    - 9/10 in eccentric group returned to pre-injury sports

Wall Squats w/ Contralateral Unload  Squats w/ Decline Slant Board
**Patellar Tendon/Quadriceps**

Leg Extension:
- Assisted Concentric
- 2-up with 1-down

**Patellar Tendon/Quadriceps**

- Lunge w/ Concentric Assist
- Leg Press w/ Unilateral Ecc Return

**Hamstring Musculature/Tendons**

- Leg Curl: 2-down & 1-up
- Swiss Ball Curl Ups w/ Unilateral Eccentric Return
Hamstring Musculature/Tendons

- Nordic Hamstring Curl

Hip Abductors/External Rotators

  - N = 32 (men & women)
  - Lower-limb kinematics
  - Ecc hip abductor & ext. rotator torques
  - Correlated with:
    - Coronal plane femur & knee movements
    - Women w/ ↑ eccentric hip abductor torque exhibited ↓ femur adduction & int. rotation
Hip External Rotators

General Lower Extremity

Assisted Walking w/Eccentric Resistance
Upper Quarter Eccentric Exercises

- Supra/infraspinatus, teres minor
- Biceps
- Periscapular muscles
- Wrist extensors

Eccentric Training: Shoulder

Evidence

- Bernhardsson 2011: N=10, no control, side lying external rotation
- Carmargo 2012: N=20, no control
- Per Jonsson 2006: N=9, no control, avoided surgery
- Holmgren 2012: N=102, RCT, specific rotator cuff eccentric exercise vs general
Scapula: Motor Control

External Rotators Standing

External Rotators Side Lying
External Rotators 90/90

Peri-scapular exercises

Biceps

Jayaseelan 2012
Evidence

- Svernlov 2001: N=30, RCT stretch vs eccentric
- Stasinopoulos 2006: N=75, eccentric vs manual vs light therapy
- Croisier 2007: N=92, general vs eccentric
- Martinez-Silvestrini 2005: N=54, RCT, eccentric vs concentric
- Tyler 2010: M=21, RCT, isotonic vs eccentric
Wrist Extensors

Practice Session
Eccentric Recovery Considerations

- Range of motion loss: timing of stretching
- Delayed onset muscle soreness
- Repeated bout effect
- Interventions
  - Cold therapy
  - Antioxidants
  - Compression
  - Time/Active rest
- Strength assessment considerations

Case 1: Shoulder Pain

Case 2: Knee Pain
Final Thoughts

- Consider indications: Do no harm!!!
  - Patient selection is more important than technique
- Intentional eccentric training:
  - Facilitates mechanotransduction & hormonal response
  - Tendon regeneration & Muscle hypertrophy
- Prescription considerations
  - Eccentric: Anything is better than “nothing”
  - Everyday patients are often not competitive athletes!
  - Use strain vs. pain and D.O.M.S to gauge intensity
  - Begin with mid-range and progress to end-range
  - Recognize BOTH progressions and regressions

Questions?