

Management of the Barbell Athlete

Dr. Chris Garcia, PT, DPT, SCS, CSCS, USAW
Shane Adamos, MS, CSCS, CF-L1



Movement Analysis



Sports Rehab



Event Coverage



Acute Injuries



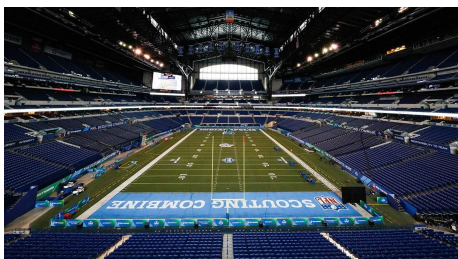
Managing Athletes



Strength & Conditioning



Speed Development



Comprehensive Management of 1 Athlete





Goal

- Keep people moving and exercising
- Provide modifications
- Guidelines on how to keep them training during the healing process
- No limitations with workouts



SPORTS
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Sports Performance

Once upon a time...

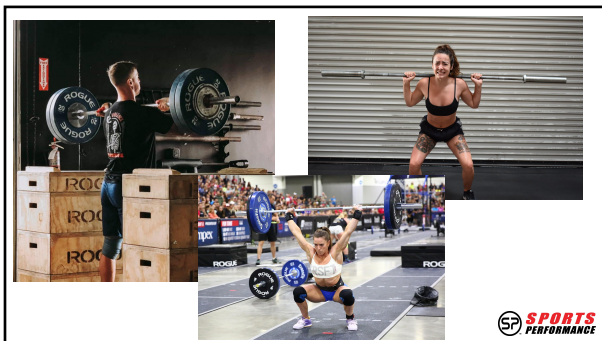


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Course Objectives

- **Evaluate and analyze barbell lifts** including: deadlifts, squat variations, and Olympic lifts, and provide feedback of biomechanical inefficiencies.
- Provide specific **modifications to barbell lifts** (deadlifts, squat variations, and Olympic lifts) for individuals experiencing pain based on clinical presentation and barbell evaluation and analysis.
- **Provide manual therapy interventions** based on clinical reasoning, evaluation, and analysis of barbell lifts.
- Develop novice **competency and comprehension of barbell lifts**, their variations, and derivatives.
- Develop **evidence-informed short and long term plan of care programs** consisting of: manual therapy, corrective exercises, and modifications and progressions of barbell lifts, based on patient goals and soft tissue healing timelines.



Patient Care

- Deeper understanding of what movements they are doing
- Questions to gain better insight
- It's not just about the location of the pain
- It's about why that pain started and what is the long-term plan to address it





Barbell Sports



Terminology: Dumbbell vs. Barbell



Terminology

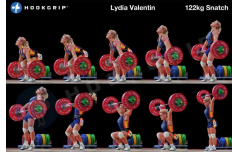
- Volume: # of muscles worked, exercises, sets, and reps during a single session
- Load: amount of weight
- Frequency: how many training sessions are performed per week
- Intensity: percentage of a person's max effort
- Tempo: the rate or speed of motion or activity
- Reps: single cycle of lifting and lowering a weight in a controlled manner
- Sets: several repetitions performed one after another with no break



The Barbell Sports: Olympic Weightlifting



Clean and Jerk



Snatch

Training program:

- Technique-focused: speed prioritized
- Heavy lifting later in cycle
- 50-75% percentages
- Accessory work
- ROM demand: max



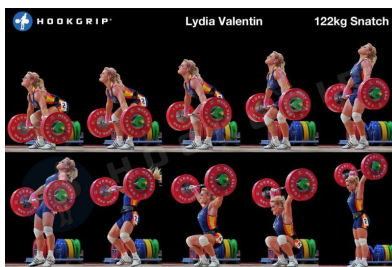
Range of motion demands: clean and jerk



CrossFit



Range of motion demands: snatch



Snatch



The Barbell Sports: Powerlifting



Squat



Deadlift
(Sumo pictured)



Bench Press

Training program:

- Volume/Strength-focused, control prioritized
- Progressively heavier lifting throughout cycle
- 70-90% percentages
- Accessory work
- ROM demand: moderate



The Barbell Sports: CrossFit



Barbell



Kettlebell/Dumbbell



Bodyweight

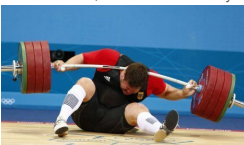
Training program

- Constantly varied functional movements performed at high intensity
- Strength/skill work (gymnastics) followed by metcon/WOD
- Performance often under fatigue with high heart rate
- ROM demand: high



Scope of the problem

- **Olympic weightlifting** Injuries: 2.4-3.3 injuries per 1000 hours training
 - Most commonly injured: Low back, knee, shoulder
 - Most often injuries to muscles and/or tendons
 - 20% acute muscle injuries, 25% overuse injury of tendons.
 - Chronicity: 30% 1-2 weeks, 24% 2 weeks to 2 years, 5% over 2 years



Aasa U, Svartholm L, Andersson F, et al. Injuries among weightlifters and powerlifters: a systematic review. *British Journal of Sports Medicine* 2017;51:211-219.



Scope of the problem

- **Powerlifting** Injuries: 1.0-4.4 injuries per 1000 hours training
 - Most commonly injured: shoulder, low back, elbow, knee
 - Most common injuries: muscle strains, tendonitis, cramps
 - 60% acute, 40% chronic
 - Chronicity: >80% shoulder, back, knee >4 weeks



Aasa U, Svartholm L, Andersson F, et al. Injuries among weightlifters and powerlifters: a systematic review. British Journal of Sports Medicine 2017;51:211-219.



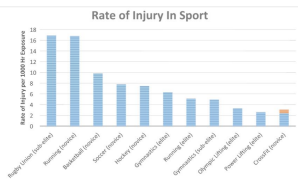
Scope of the problem: Barbell sports

Study	Sport	Injury rate per 1,000 hours	Most common regions
Winwood	Strongman	5.50	Low back
Keogh (2006)	Powerlifting	4.40	Shoulder
Quinney (1997)	Powerlifting	3.70	Low back
Calhoun (1999)	Olympic weightlifting	3.30	Low back
Hak (2013)	CrossFit	3.10	Shoulder
Raske and Norlin (2000)	Olympic weightlifting	2.60	Low back
Raske and Norlin (2000)	Powerlifting	2.60	Shoulder
Haykowsky (1999)	Powerlifting	1.10	Low back and shoulder
Siewe (2011)	Powerlifting	1.00	Shoulder
Eberhardt (2007)	Bodybuilding	1.00	Not specified
Brown (1986)	Powerlifting	0.84	Shoulder
Siewe (2014)	Bodybuilding	0.24	Shoulder

<https://www.strengthandconditioningresearch.com/2014/07/08/injury-strength-sports/>



Scope of the problem: All sports



Activity	Injury Rate (per 1000 h)	Reference
Bodybuilding (competitive)	0.24	Siewe et al., 2014 (1)
Crossfit, Olympic weight lifting, powerlifting, gymnastics	3.1	Hak et al., 2013 (2)
Team sports (practices)	4	Hootman et al., 2007 (3)
Running	10	Hespanhol Junior et al., 2017 (4)
Team sports (games)	14	Hootman et al., 2007 (3)

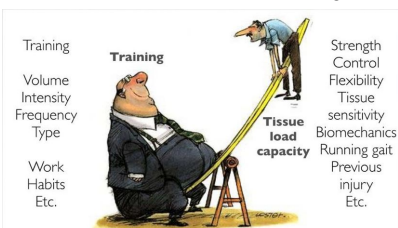
<https://sites.psu.edu/sinofe/15/2015/10/12/crossfit-sport-or-hed/>



Unique Needs of Barbell Athletes



Unique Needs of Barbell Athletes: Load Management



Blanch, P. Gabbal T. Has the athlete trained enough to return to play safely? The acute:chronic workload ratio permits clinicians to quantify a player's risk of subsequent injury. *British Journal of Sports Medicine* 2017 50(8):471-475.



In the absence of recent trauma....

Pain is your body asking for a change!

Smith BE, Hendrick P, Bateman M, et al. Musculoskeletal pain and exercise—challenging existing paradigms and introducing new. *British Journal of Sports Medicine* 2019;53:507-512.



Why does it want change?

Training or Overtraining?

- Stressors
 - Load: Exercise, muscular stress, manual work: picking up kids, home improvement, career
 - Duration: Static postures
 - Psychosocial (internal) Load: Mental stress, cognitive work
 - Fatigue

Recovery or Under-recovery?

- De-stressors
 - Sleep/Rest
 - Nutrition
 - Relaxation/Meditation
 - Movement-Blood Flow

Moseley, GL, & Butler DS. Fifteen years of explaining pain: The past, present, and future. *Journal of Pain*. 2015 16(9):807-813.
Lowe A, Diener J, Butler DS, & Painscience EJ. The effect of neuroscience education on pain, disability, anxiety, and stress in chronic musculoskeletal pain. *Arch Phys Med Rehabil*. 2011 92(12):2041-56.



Recovery Strategies

What's in your cup?

Pain is the balance between all the things that are harmful to you (what's in your cup) and all the things that are good for you (building a bigger cup)



CASES



Case 1 Intro: Back Pain and Deadlifting

Jose: 42 yo male in powerlifting and CrossFit 6 days/wk; LBP for 5 years that he attributes to an unhealed work injury

Aggravators: Heavy Squats, Heavy DL, High volume deadlifts, KB swings, bothers him when he sits in the patrol car

Ease: Foam rolling low back, lacrosse ball in glutes

Social: law enforcement with shift work, 2 kids, long days with sometimes 12h between meals

Wellness: sleeps 4-5 hours per night occasional all-nighters with daytime sleeping, nutrition: usually 2 large meals on work days, 4 meals on non-work days. Works out after work shifts.



What do we want to see? What do we want to test?

Jose: 42 yo male in powerlifting and CrossFit 6 days/wk; LBP for 5 years that he attributes to an unhealed work injury

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Case 2 Intro: Knee Pain and Squatting

Maggie: 35 yo female in Olympic lifting 4 days/wk developed R knee pain 1 month prior when percentages increased; Attributes it to years of running in high school coming back to haunt her

Aggravators: All Squatting, BS better than FS, OHS

Ease: Foam rolling, TheraGun on quad

Social: Three kids, all involved in sports, works part time from home

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What do we want to see? What do we want to test?

Maggie: 35 yo female in Olympic lifting 4 days/wk developed R knee pain 1 month prior when percentages increased; Attributes it to years of running in high school coming back to haunt her

Aggravators: All Squatting, BS better than FS, OHS

Ease: Foam rolling, TheraGun on quad

Social: Three kids, all involved in sports, works part time from home

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General Concepts - Joint by joint stability/mobility



General Concepts - Biomechanics

- ☐ Center of Mass
 - ☐ S2 (without external load)
- ☐ Moment Arm
 - ☐ Joint axis distance from line of action
- ☐ Line of action
 - ☐ Barbell path
- ☐ Net vectors
 - ☐ Anterior/posterior change in CoM can change the resultant line of action.



Learn the Lifts - Deadlift



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Learn the Lifts - Deadlift



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Learn the Lifts - Deadlift

Hinge Pattern

- ☐ Pull an external object off the floor
- ☐ Hip dominant movement, minimal knee movement
- ☐ Long moment arm

Points of Performance

- ☐ Neck/back in neutral
- ☐ Shoulders in front of the bar
- ☐ Bar over midfoot
- ☐ Hips & Shoulders rise at same time
- ☐ Full extension at top position



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Learn the Lifts - Deadlift

Common Faults

- ☐ Lumbar flexion⁹
- ☐ Excessive neck extension
- ☐ Weight loses contact with body
- ☐ Hips rise faster than shoulders



Learn the Lifts - Squat

Hip AND Knee Pattern

- ☐ Lower center of mass
- ☐ Synergy of all lower body joints and musculature

Points of Performance

- ☐ Shoulder width stance^{1,2}
- ☐ Hips move back and down
- ☐ Hips descend lower than knees (break parallel)
- ☐ Back position maintained
- ☐ Knees track over toes
- ☐ Heels stay down



Learn the Lifts - Squat

Common Faults

- ☐ Excessive lumbar flexion at bottom
- ☐ Hips rise faster than shoulders
- ☐ Valgus/varus knee motion^{1,3,4}
- ☐ Heels come off ground³



Learn the Lifts - Squat

Variations

- ☐ Front Squat
 - ☐ In front of chest at clavicle^{1,2}
- ☐ Back Squat
 - ☐ High bar: above acromion^{1,2}
 - ☐ Low bar: below acromion^{1,2}
- ☐ Overhead Squat



Getting to the root of the problem

- Joint range of motion (mobility): capacity
- Strength or movement quality (motor control): capability
- Training/volume issues

Kristof K. Redden J, Sabick MB, and Harris C. Weightlifting performance is related to kinematic and kinetic patterns of the hip and knee joints. J Strength Cond Res 2012;26:1838-1844.



PAIN LOCATION	Deadlift	Front Squat	Back Squat	Overhead Squat	Clean	Clean & Jerk	Snatch
Cervical	✓			✓	✓	✓	✓
Thoracic		✓	✓	✓	✓	✓	✓
Lumbar	✓	✓	✓	✓	✓	✓	✓
Shoulder			✓	✓		✓	✓
Elbow		✓			✓	✓	✓
Wrist		✓		✓	✓	✓	✓
Hip		✓	✓	✓	✓	✓	✓
Knee		✓	✓	✓	✓	✓	✓
Ankle		✓	✓	✓	✓	✓	✓



MOBILITY	Deadlift	Front Squat	Back Squat	Overhead Squat	Clean	Clean & Jerk	Snatch
Cervical (EXT)	✓			✓	✓	✓	✓
Thoracic (EXT)		✓	✓	✓	✓	✓	✓
Lumbar (FLEX)	✓	✓	✓	✓	✓	✓	✓
Shoulder (FLEX/IR/ER)		✓	✓	✓	✓	✓	✓
Elbow (FLEX/EXT)		✓		✓	✓	✓	✓
Wrist (EXT)		✓		✓	✓	✓	✓
Hip (FLEX/EXT/IR)		✓	✓	✓	✓	✓	✓
Knee (FLEX)		✓	✓	✓	✓	✓	✓
Ankle (DF)		✓	✓	✓	✓	✓	✓



Deadlift

- Sagittal
 - Excessive cervical extension (motor control)
 - Rounding of the spine (lumbar/hip or motor control)



Front squat

- Sagittal
 - Elbows drop (lat length or thoracic extension)
 - Rounding of the spine (hips or ankles)
 - Lack of upright torso (hips or ankles)
 - Anterior knee position (ankles or hips, or motor control)
 - Posterior: asymmetrical depth or bar position (hip, knee or ankle on one side)
- Transverse
 - Knee valgus (motor control)



Back squat

- Sagittal
 - Rounding of the spine (hips or ankles)
 - Lack of upright torso (hips or ankles, shoulder ER)
 - Butt wink (hips or ankles)
 - Anterior knee position (ankles or hips, or motor control)
 - Posterior: asymmetrical depth or bar position (hip, knee or ankle on one side)
- Transverse
 - Knee valgus (motor control)



Hartmann H, Wirth K, Kusemann M. Analysis of the load on the knee joint and vertebral column with changes in squatting depth and weight load. *Sports Med* 2013;43(10):993-1005.

Lorenzetti S, Orlermann M, Zeidler F, Zimmer P, Jenlich L, List R, Taylor WR, Schellenberg F. How to squat? Effects of various stance widths, foot placement angles and level of experience on knee, hip and trunk motion and loading. *BMC Sports Sci Med Rehabil* 2016;10:14.



Overhead squat

- Sagittal
 - Rounding of the spine (hips or ankles)
 - Lack of upright torso (hips or ankles, shoulder flexion)
 - Butt wink (hips or ankles)
 - Anterior knee position (ankles or hips, or motor control)
 - Posterior: asymmetrical depth or bar position (hip, knee, ankle or shoulder on one side)
 - Posterior: shoulder rotation position (motor control, or thoracic or shoulder)
- Transverse
 - Knee valgus (motor control)



Edmonston S, Ferguson A, Ippertiel P, Romningen L, Sodeland S, & Barclay L. Clinical and radiological investigation of thoracic spine extension motion during bilateral arm elevation. *Journal of Orthopaedic & Sports Physical Therapy* 2012; 42:10, 861-868.



Deadlift	Front Squat	Back Squat	Overhead Squat
Excessive neck extension	Elbows drop (lat length or thoracic extension)	Rounding of the spine (hips or ankles)	Rounding of the spine (hips or ankles)
Rounding of the spine	Rounding of the spine (hips or ankles)	Lack of upright torso (hips or ankles, shoulder ER)	Lack of upright torso (hips or ankles, shoulder flexion)
	Butt wink (hips or ankles)	Butt wink (hips or ankles)	Butt wink (hips or ankles)
	Anterior knee position (ankles or hips, or motor control)	Anterior knee position (ankles or hips, or motor control)	Anterior knee position (ankles or hips, or motor control)
	Posterior: asymmetrical depth or bar position (hip, knee or ankle on one side)	Posterior: asymmetrical depth or bar position (hip, knee or ankle on one side)	Posterior: asymmetrical depth or bar position (hip, knee, ankle or shoulder on one side)
			Posterior: shoulder rotation position (motor control, or thoracic or shoulder)
	Knee valgus (motor control)	Knee valgus (motor control)	Knee valgus (motor control)



Cervical

- Joint ROM: extension
- Test: seated/standing neck extension
- Goal: chin 70 degrees (near vertical)
- Lift: deadlift
- Movement problem: looking too high up



Thoracic

- Joint ROM: extension
- Test: seated thoracic extension with knees elevated
- Goal: 20 degrees
- Lift: squat variations, clean, snatch
- Movement problem: lack of upright torso or rounding of the spine



Lumbar

- Joint ROM: flexion
- Test:
 - Standing forward bend
 - Supine SLR
- Goal:
 - 70 degree sacral angle
 - SLR to 70 degrees
- Lift: squat variations, clean, snatch
- Movement problem: poor hip dissociation or rounding of the spine



Demers E, Pendergast J, Radevich V, Preuss R. The effect of stance width and anthropometrics on joint range of motion in the lower extremities during a back squat. Int J Exerc Sci 2018;11(1):764-775.



Shoulder

- Joint ROM: flexion, IR, ER
- Test:
 - Supine shoulder flexion (joint vs lat length)
 - Standing PVC high pull
 - Standing IR/ER
- Goal:
 - Flexion: 180 degrees
 - IR: 70 degrees
 - ER: 90 degrees



Elbow

- Joint ROM: flexion
- Test:
 - Standing elbow flexion to shoulders
- Goal:
 - Flexion: 140 degrees, touch shoulders



Wrist

- Joint ROM: extension
- Test:
 - Standing prayer stretch
- Goal:
 - Extension: 70-85 degrees, touch shoulders



Hip

- Joint ROM: flexion, IR
- Test:
 - Squat
 - Standing hip rotation
 - Supine knees to chest
 - Supine hip IR
- Goal:
 - Flexion: 120 degrees
 - IR: 45 degrees
 - Pelvis stays on table
- Lift: squat variations, clean, snatch
- Movement problem: butt wink, rounding of the spine, lack of upright torso, anterior knee position, asymmetrical hip or bar position

List R, Guley T, Stoop M, Lorenzetti S. Kinematics of the trunk and the lower extremities during restricted and unrestricted squats. J Strength Cond Res 2013;27(6):1529-1538.



Knee

- Joint ROM: flexion
- Test:
 - Supine heel to buttock
- Goal:
 - Flexion: 140 degrees
 - Heel to buttock
- Lift: squat variations, clean, snatch
- Movement problem: lack of upright torso, asymmetrical hip or bar position

Zelle J, Brank M, Loeffen R, De Waal Malefijt M, Verdonchot N. Thigh-calf contact force measurements in deep knee flexion. Clin Biomech 2007;22(7):821-826.

Smith SM, Cockburn RA, Hemmerich A, Li RM, Wyss UP. Tibiofemoral joint contact forces and knee kinematics during squatting. Gait posture 2008;27(3):376-386.



Ankle

- Joint ROM: DF
- Test:
 - Knee to wall DF test
- Goal:
 - DF: 10 degrees
 - One fist, four finger width or 4"
- Lift: squat variations, clean, snatch
- Movement problem: butt wink, rounding of the spine, lack of upright torso, anterior knee position, asymmetrical hip or bar position



Chiu LZ, VorGaza GL, Jean LM. Net joint moments and muscle activation in barbell squats without and with restricted anterior leg rotation. J sports sci 2017;35(1):35-43.



Beardsley C. The Functional Movement Screen: a review
Strength & Cond Journal. 2014
36(5):72-80.

SCREEN	TEST
Cervical	-Standing neck extension
Thoracic	-Seated thoracic extension
Lumbar	-Standing forward bend -Supine SLR
Shoulder	-Standing functional IR/ER -Standing PVC high pull -Supine shoulder flexion
Elbow	-Standing elbow flexion
Wrist	-Standing prayer position
Hip	-Squat -Standing hip rotation -Supine knees to chest -Supine hip IR
Knee	-Supine heel to buttock
Ankle	-Half kneeling knee to wall



SCREEN	TEST	ATTENDEE EXAMPLE
Cervical	-Standing neck extension	
Thoracic	-Seated thoracic extension	
Lumbar	-Standing forward bend -Supine SLR	
Shoulder	-Standing functional IR/ER -Standing PVC high pull -Supine shoulder flexion	
Elbow	-Standing elbow flexion	
Wrist	-Standing prayer position	
Hip	-Squat -Standing hip rotation -Supine knees to chest -Supine hip IR	
Knee	-Supine heel to buttock	
Ankle	-Half kneeling knee to wall	



Case 1 PT Evaluation:

Jose: 42 yo male in CrossFit 6 days/wk LBP for 5 years that he attributes to an unhealed work injury

Aggravators: Heavy Squats, Heavy DL, High volume deadlifts, KB swings, bothers him when he sits in the patrol car

Ease: Foam rolling low back, lacrosse ball in glutes

Social: law enforcement with shift work, 2 kids, long days with sometimes 12h between meals

Wellness: sleeps 4-5 hours per night occasional all-nighters with daytime sleeping, nutrition: usually 2 large meals on work days, 4 meals on non-work days. Works out after work shifts.

What do we want to assess??

Discuss!!



Case 1 PT Evaluation: LBP and DL

Jose: 42 yo male in CrossFit 6 days/wk LBP for 5 years that he attributes to an unhealed work injury

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Wellness: sleeps 4-5 hours per night occasional all-nighters with daytime sleeping, nutrition: usually 2 large meals on work days, 4 meals on non-work days. Works out after work shifts.

- **Movement Assessment:**
 - Poor hip/lumbar dissociation
 - Limited ankle DF mobility
 - Feels low back tension in hip hinge
- **Table Assessment:**
 - Pain with forward bend
 - TTP at lumbar paraspinals
 - Hip ROM stiff (FL, IR)
 - Straight Leg Raise to 45 degrees



Case 2 PT Evaluation:

Maggie: 35 yo female in Olympic lifting 4 days/wk developed R knee pain 1 month prior when percentages increased

Aggravators: All Squatting, BS better than FS, OHS

Ease: Foam rolling, TheraGun on quad

Social: Three kids, all involved in sports, works part time from home

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What do we want to assess??

Discuss!!



Case 2 PT Evaluation: Knee Pain and Squatting

Maggie: 35 yo female in Olympic lifting 4 days/wk developed R knee pain 1 month prior when percentages increased. Attributes it to years of running in high school coming back to haunt her

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- **Movement Assessment:**
 - forward knee with squat
 - initiates squat from knees
 - unable to feel hamstrings in hinge pattern
 - unable to SL squat bodyweight without pain
- **Table Assessment:**
 - pain localized to patellar tendon
 - TTP patellar tendon
 - ROM full but sensation of anterior knee tightness in full flexion
 - Sensation of quad tightness



SCREEN	TEST
Cervical	-Standing neck extension
Thoracic	-Seated thoracic extension
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Shoulder	-Standing functional IR/ER -Standing PVC high pull -Supine shoulder flexion
Elbow	-Standing elbow flexion
Wrist	-Standing prayer position
Hip	-Squat -Standing hip rotation -Supine knees to chest -Supine hip IR
Knee	-Supine heel to buttock
Ankle	-Half kneeling knee to wall



Case 1 PT Evaluation: LBP and DL

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- **Movement Assessment:**
 - Poor hip/lumbar dissociation
 - Limited ankle DF mobility
 - Feels low back tension in hip hinge
- **Table Assessment:**
 - Pain with forward bend
 - TTP at lumbar paraspinals
 - Hip ROM stiff (FL, IR)
 - Straight Leg Raise to 45 degrees



How Would You Address This Athlete?

Problem List:

ROM/Flexibility Issues:

Limited Ankle DF

Limited Hip ROM: FL, IR


Limited Hamstring Flexibility

No **Strength** Issues Found

Needs Change of **Movement Patterns!**

Avoid lumbar rounding with initiation of lift (Teach proper hip hinge)

Avoid lumbar flexion at bottom of squat (hip ROM issue)



Treatment Plan: Case 1

Step 1: Pain Relief for Lumbar Strain

- Soft Tissue Mobilization to Lumbar Paraspinals, QL, Glutes, even Hamstrings if needed
- Myofascial Decompression ("cupping") to Lumbar Paraspinals/QL
- MFD with movement: Lumbar FL
- Appropriate Modalities (e-stim, ice or heat, depending on acute vs sub-acute stage)
- Teach self-mobilization techniques, such as lumbar foam rolling or lacrosse ball (review, as this patient is already doing this)
- Kinesiotape along lumbar paraspinals

Step 2: Prevent From Recurring

1. Joint ROM
2. Movement Quality
3. Training/Volume Issues (discussed in depth later)



Treatment Plan: Case 1

Step 2: Prevent from Recurring (Address ROM)

Ankle Dorsiflexion

- Posterior Talocrural Joint Mobs (sitting or standing)
- Talocrural Distraction, grade V (Belt)
- Posterior Ankle Glide (Banded)

Anterior tibial glide (banded)

Limited Hip ROM

- Hip FL/Hamstring Stretch with Posterior Glide (Banded)
- Pigeon Pose with Lateral Glide (Banded)



Treatment Plan: Case 1

Step 2: Prevent from Recurring (Movement Patterns)

Improve Hip Hinge:

- Teach Hip Hinge (PVC, Banded), Good Mornings (Banded)
- Deadlift Variations: Romanian Deadlift, Rack Pull, DL off blocks/platform, Trap Bar DL, Sumo DL, Suitcase DL

Improve Upright Squat:

- TRX Squats (or holding on to rack)
- Modification: heel lifts (shoes or heels on plates)
- Modification: box squat to decrease squat depth

**Encourage adequate warm-up to include the HEP to address ROM/flexibility and muscle activation exercises



Load Management/Modifications

Low Back Pain and Deadlifting

- Load: Decrease weight
- Tempo: eccentrics
- ROM: Limit to pain-free (3/10)
- Variation: Romanian Deadlift, Rack Pull, DL off blocks/platform, Trap Bar DL, Sumo DL, Suitcase DL



How Would *You* Address This Athlete?

Problem List:

Needs Change of Movement Patterns!

- Excessive anterior knee shift with squats
- Quad dominant/Lacking glute activation



Case 2 PT Evaluation: Knee Pain and Squatting

Maggie: 35 yo female in Olympic lifting 4 days/wk developed R knee pain 1 month prior when percentages increased. Attributes it to years of running in high school coming back to haunt her

Aggravators: All Squatting, BS better than FS, OHS

Ease: Foam rolling, TheraGun on quad

Social: Three kids, all involved in sports, works part time from home

Wellness: sleeps 6 hours per night, nutrition: often on the go, salads with chicken, shakes, stressed by daily commitments

- Movement Assessment:
 - Forward knee with squat
 - initiates squat from knees
 - unable to feel hamstrings in hinge pattern
 - Pain with SL squat
- Table Assessment:
 - pain localized to patellar tendon
 - TTP patellar tendon
 - ROM full but sensation of anterior knee tightness in full flexion
 - Sensation of quad tightness



Treatment Plan: Case 2

Step 1: Desensitization of Patellar Tendon

- Soft Tissue Mobilization to Quads/Patellar Tendon
- IASTM Techniques to Patellar Tendon
- Myofascial Decompression ("cupping") to Quad
- Teach self-mobilization techniques, such as quad foam rolling
- Patellar Tendonitis Strap with Pre-Wrap

Step 2: Prevent From Recurring

1. Joint ROM
2. Movement Quality - Primary Focus
3. Training/Volume Issues



Treatment Plan: Case 2

Step 2: Prevent from Recurring (Movement Patterns)

Block excessive anterior knee shift with squat:

Wall Squats
SL Squat to Box
TRX Squats

Glute activation to decrease anterior strain:

Banded Goblet Squats

Modification: Change stance or toe angle

Modification: Back Squat instead of Front Squats

Modification: Squats to Box

Squat Variation: Goblet Squats, high bar with back squat, Reverse Lunge



Load Management/Modifications

Knee Pain and Squatting

- Load: Decrease weight
- Tempo Squats
- ROM: Limit to pain-free (3/10)
- Variation: Box Squat (with Goblet, FS, BS-start high, progress with depth), Reverse Lunge, Modify Toe or Foot Angle



Load Management

TRAINING WITH AN INJURY

The key to coming back from an injury is not foam rolling or "releasing muscles". We need to modify volume, intensity, and mode of training in order to build capacity.

@EMBALLIFESTYLE

Rest

Train energy systems

Train surrounding body parts

Training modification

Manipulate tempo and TUT

Load and volume management

SP

SPORTS PERFORMANCE

Load Management

SHOULD I KEEP TRAINING?

A helpful flowchart to determine whether or not you should keep training.

@EMBALLIFESTYLE

Did it feel better after 1-2 days of rest?
YES → KEEP ON TRAINING
NO → Can you train at a lighter weight comfortably?
YES → KEEP ON TRAINING
NO → Can you decrease the range of motion?
YES → KEEP ON TRAINING
NO → Can you change the variation of the movement?
YES → KEEP ON TRAINING
NO → Can you change the exercise but work out the same body part?
YES → KEEP ON TRAINING
NO → SEE A HEALTHCARE PRACTITIONER

Load

ROM

Movement

Type of exercise

SP

SPORTS PERFORMANCE

	MOBILITY (CAPACITY)	MOTOR CONTROL (CAPABILITY)	TRAINING / VOLUME
Cervical			
Thoracic			
Lumbar			
Shoulder			
Elbow			
Wrist			
Hip			
Knee			
Ankle			

SP

SPORTS PERFORMANCE

Reflect.....

What's one new piece of information you learned today?

Think of a current patient who may benefit from information you have acquired today!

Are you comfortable with incorporating the movements into your own workout routine? Comfortable incorporating movements into a POC?

What immediate changes can you make on Monday?

What are you looking forward to about tomorrow's content?



Management of the Barbell Athlete

Day 2



Case 3 Intro: Shoulder Pain Pressing

Alexa: 30 yo female former gymnast in Olympic Lifting, currently Olympic lifter 4 days/wk; Reporting anterior shoulder pain bothering her with lifting overhead; Attributes to impingement and worries that continuing to lift will ruin her shoulders because of the constant pinching

Aggravators: Snatch, OH Press, OHS, Push Press, Push Jerk

Ease: Lacrosse Ball in traps, posterior shoulder

Social: Gym manager, coach

Wellness: sleeps 4-5 hours per night to coach early morning class; nutrition: lean protein, veggies with majority of carbs close to workouts;



What do we want to see? What do we want to test?

Alexa: 30 yo female former gymnast in Olympic Lifting, currently Olympic lifter 4 days/wk; Reporting anterior shoulder pain bothering her with lifting overhead; Attributes to impingement and worries that continuing to lift will ruin her shoulders because of the constant pinching

Aggravators: Snatch, OH Press, OHS, Push Press, Push Jerk

Ease: Lacrosse Ball in traps, posterior shoulder

Social: Gym manager, coach

Wellness: sleeps 4-5 hours per night to coach early morning class; nutrition: lean protein, veggies with majority of carbs close to workouts;



Case 4 Intro: Back Pain Deadlifting, Squatting

William: 36 yo male Olympic Lifter reporting hip and back tightness that bothers him during and after training deadlifts, squats, cleans, snatches. Attributes to "getting older, it's all downhill after 30!"

Aggravators: DL, Squat, full cleans, full snatch, sleeping on back, walking his dogs, end of the day after long periods of standing

Ease: Good warmup, foam rolling, power clean, power snatch

Social: Construction contractor, in the field for 30h/wk

Wellness: sleeps 7.5-8h/night, nutrition: 3 big meals per day: high protein, high carb, high vegetable; Stress: moderate as wife is in between jobs



What do we want to see? What do we want to test?

William: 36 yo male Olympic Lifter reporting hip and back tightness that bothers him during and after training deadlifts, squats, cleans, snatches. Attributes to "getting older, it's all downhill after 30!"

Aggravators: DL, Squat, full cleans, full snatch sleeping on back, walking his dogs, end of the day after long periods of standing

Ease: Good warmup, foam rolling, power clean, power snatch

Social: Construction contractor, in the field for 30h/wk

Wellness: sleeps 7.5-8h/night, nutrition: 3 big meals per day: high protein, high carb, high vegetable; Stress: moderate as wife is in between jobs



Intro to Lifts - Weightlifting

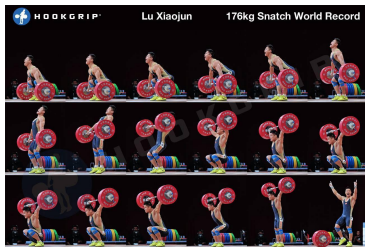
Olympic Sport involving three movements:

- ☐ Snatch
- ☐ Clean
- ☐ Jerk

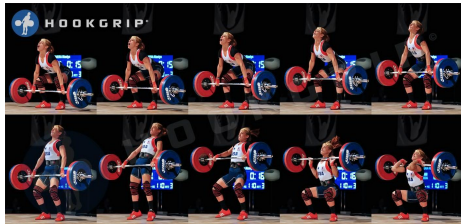
**Clean & Jerk can, and are, trained separately, but combined for competition.*



Intro to Lifts - Snatch



Intro to Lifts - Clean



Intro to Lifts - Jerk



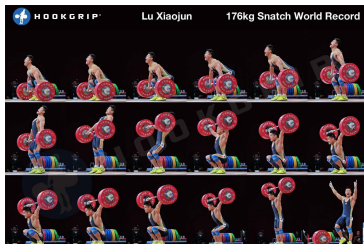
Learn the Lifts - Snatch/Clean & Jerk

Common Points of Performance

- ☐ Use lower body musculature to create an impulse to bring the barbell to a certain height
- ☐ Hips/shoulders rise at same rate from bottom position
- ☐ Power position
- ☐ Jump/shrug
- ☐ Triple extension
- ☐ Pull/push body down against an inert object to receive barbell



Intro to Lifts - Snatch



Learn the Lifts - Snatch

- Points of Performance
- ❑ Receive barbell overhead with elbows extended



Intro to Lifts - Clean



Learn the Lifts - Clean

- Points of Performance
- ❑ Receive barbell in a front rack position



Intro to Lifts - Jerk



Learn the Lifts - Jerk

Points of Performance

- ☐ Starting from the front rack position after fully recovering from the clean
- ☐ Dip
 - ☐ Vertical torso
 - ☐ Hips/knees slightly flexed
 - ☐ Triple extension
- ☐ Press the body down/under the barbell to overhead position
 - ☐ Power Jerk: Power squat
 - ☐ Split Jerk: Lunge



Modifiers to Weightlifting Movements

Common terminology to in varying weightlifting movements

- ☐ Power
 - ☐ At completion of the movement, the bar is received in a partial squat position.
 - ☐ i.e. "Power clean" or "Power Snatch"
- ☐ Hang
 - ☐ The movement is started with the barbell off the ground.
 - ☐ i.e. "Hang clean" or "Hang snatch"
- ☐ Combination of both "hang" and "power"
 - ☐ Utility in limiting end-range hip and knee flexion.
 - ☐ i.e. "Hang power clean"



Variations of Lifts

- **Olympic Lifting**
 - Clean & Jerk
 - Snatch
 - Variations: Power, Hang, Full

Duba J, Kraemer W J, and Martin G. A 6-step progression model for teaching the hang power clean. *Strength Cond J* 2007;29:28-35.
Duba J, Kraemer W J, and Martin G. Progressing from the hang power clean: A 4-step model. *Strength Cond J* 2009;31:58-66.



Getting to the root of the problem

- Joint range of motion (mobility): capacity
- Strength or movement quality (motor control): capability
- Training/volume issues

Verhoeff, Wesley J, Miller, Sarah K, Oldham, Anthony R.H., & Cronin, J. Coaching the Power Clean: A constraints led approach. *Strength and Conditioning Journal*. 2020;42(2):16-25.
Hornsbay G, Cedar W, Mizuguchi S, and Stone M. The power position—Characteristics and coaching points. *NSCA Coach* 2018;5:6-12.



Clean

- Deadlift → front squat

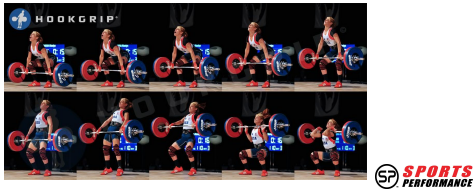


Comfort P, Fletcher C, and McMahon JJ. Determination of optimal loading during the power clean in collegiate athletes. *J Strength Cond Res* 2012;26:2370-2374.



Clean

- Deeper start position: ankle and hip
- Transition: hip extension, shoulder IR



Clean and Jerk

- Deadlift → front squat → overhead press



Clean and Jerk

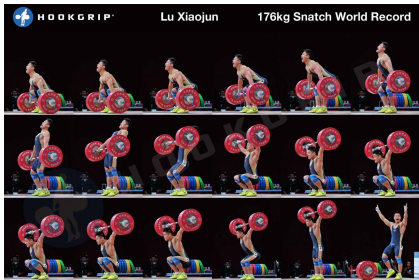
- Start position
- Hip extension (DL)
- Shoulder IR
- Shoulder flexion
- Hip extension (SL)



Snatch

- Deadlift → overhead squat





Deadlift

- Sagittal
 - Excessive cervical extension (motor control)
 - Rounding of the spine (lumbar/hip or motor control)



Front squat

- Sagittal
 - Elbows drop (lat length or thoracic extension)
 - Rounding of the spine (hips or ankles)
 - Lack of upright torso (hips or ankles)
 - Anterior knee position (ankles or hips, or motor control)
 - Posterior: asymmetrical depth or bar position (hip, knee or ankle on one side)
- Transverse
 - Knee valgus (motor control)



Overhead squat

- Sagittal
 - Rounding of the spine (hips or ankles)
 - Lack of upright torso (hips or ankles, shoulder flexion)
 - Butt wink (hips or ankles)
 - Anterior knee position (ankles or hips, or motor control)
 - Posterior: asymmetrical depth or bar position (hip, knee, ankle or shoulder on one side)
 - Posterior: shoulder rotation position (motor control, or thoracic or shoulder)
- Transverse
 - Knee valgus (motor control)



Split Squat

- Sagittal
 - Extension of the spine (hips)
 - Lack of upright torso (hips or ankles, shoulder flexion)
 - Anterior knee position (ankles or hips, or motor control)
 - Posterior: bar position (elbow or shoulder on one side)
 - Posterior: shoulder rotation position (thoracic or shoulder)
- Transverse
 - Knee valgus (motor control)



Round Robin Table Assessment

- Shoulder Mobility (IR)
- Elbow Mobility (extension)
- Hip Mobility (extension DL and SL)
- Knee Mobility (extension)
- Split Squat (hip extension)



PAIN LOCATION	Deadlift	Front Squat	Back Squat	Overhead Squat	Clean	Clean & Jerk	Snatch
Cervical	✓			✓	✓	✓	✓
Thoracic		✓	✓	✓	✓	✓	✓
Lumbar	✓	✓	✓	✓	✓	✓	✓
Shoulder			✓	✓		✓	✓
Elbow		✓			✓	✓	✓
Wrist		✓		✓	✓	✓	✓
Hip		✓	✓	✓	✓	✓	✓
Knee		✓	✓	✓	✓	✓	✓
Ankle		✓	✓	✓	✓	✓	✓



MOBILITY	Deadlift	Front Squat	Back Squat	Overhead Squat	Clean	Clean & Jerk	Snatch
Cervical (EXT)	✓			✓	✓	✓	✓
Thoracic (EXT)		✓	✓	✓	✓	✓	✓
Lumbar (FLEX)	✓	✓	✓	✓	✓	✓	✓
Shoulder (FLEX/IR/ER)		✓	✓	✓	✓	✓	✓
Elbow (FLEX/EXT)		✓		✓	✓	✓	✓
Wrist (EXT)		✓		✓	✓	✓	✓
Hip (FLEX/EXT/IR)		✓	✓	✓	✓	✓	✓
Knee (FLEX)		✓	✓	✓	✓	✓	✓
Ankle (DF)		✓	✓	✓	✓	✓	✓



SCREEN	TEST	
Cervical	-Standing neck extension	-Full -Hang (high, above, below, mid-shin) -Power (2", 4", 6")
Thoracic	-Seated thoracic extension	
Lumbar	-Standing forward bend -Supine SLR	
Shoulder	-Standing functional IR/ER -Standing PVC high pull -Supine shoulder flexion	
Elbow	-Standing elbow flexion -Standing elbow extension	
Wrist	-Standing prayer position	
Hip	-Squat -Split squat (hands OH) -Standing hip rotation -Standing multi-segmental extension (DL) -Supine knees to chest -Supine hip IR -Supine Thomas test (SL)	
Knee	-Supine heel to buttock -Supine TKE	
Ankle	-Half kneeling knee to wall	



Deadlift	Front Squat	Back Squat	Overhead Squat
Excessive neck extension	Elbows drop (lat length or thoracic extension)	Rounding of the spine (hips or ankles)	Rounding of the spine (hips or ankles)
Rounding of the spine	Rounding of the spine (hips or ankles)	Lack of upright torso (hips or ankles, shoulder ER)	Lack of upright torso (hips or ankles, shoulder flexion)
	Butt wink (hips or ankles)	Butt wink (hips or ankles)	Butt wink (hips or ankles)
	Anterior knee position (ankles or hips, or motor control)	Anterior knee position (ankles or hips, or motor control)	Anterior knee position (ankles or hips, or motor control)
	Posterior: asymmetrical depth or bar position (hip, knee or ankle on one side)	Posterior: asymmetrical depth or bar position (hip, knee or ankle on one side)	Posterior: asymmetrical depth or bar position (hip, knee, ankle or shoulder on one side)
			Posterior: shoulder rotation position (motor control, or thoracic or shoulder)
	Knee valgus (motor control)	Knee valgus (motor control)	Knee valgus (motor control)



Clean	Clean and Jerk	Snatch
Stripper: hips first	Dip: Anterior knee position (ankles or motor control)	Stripper: hips first
Limited hip or knee extension (hip or knee mobility, motor control)	Transition: Limited hip or knee extension	Limited hip or knee extension (hip or knee mobility, motor control)
Jumper: feet move forward	Receiving: lumbar extension (hip or motor control), anterior knee position (motor control)	Lack of upright torso (hips or ankles, shoulder flex)
Butt wink (hips or ankles)	Forward bar position: shoulder (mobility or motor control)	Forward bar position: shoulder (IR or flexion mobility or motor control)
	Anterior knee position (motor control)	Anterior knee position (ankles or hips, or motor control)
Posterior: asymmetrical depth or bar position (hip, knee or ankle on one side)	Posterior: asymmetrical depth or bar position (shoulder, elbow, wrist, hip, knee or ankle on one side)	Posterior: asymmetrical depth or bar position (shoulder, elbow, wrist, hip, knee or ankle on one side)
	Knee valgus (motor control)	Knee valgus (motor control)



Case 3 PT Evaluation: Shoulder Pain Pressing

Alexa: 30 yo female former gymnast in Olympic Lifting, currently Olympic lifter 4 days/wk; Reporting anterior shoulder pain bothering her with lifting overhead; Attributes to impingement and worries that continuing to lift will ruin her shoulders because of the constant pinching

Aggravators: Snatch, OH Press, Push Press, Push Jerk

Ease: Lacrosse Ball in traps, posterior shoulder

Social: Gym manager, coach

Wellness: sleeps 4-5 hours per night to coach early morning class; nutrition: lean protein, veggies with majority of carbs close to workouts;

Movement Assessment:

- Snatch: Shoulders IR, Forward torso, lumbar hyperextension
- Squat: vertical shin angle

Table Assessment:

- Hypermobility Shoulders
- Sensitivity to Shoulder IR
- Pain at resisted ER at 90/90
- +Anterior Apprehension
- Kneeling wall DF: 2"



How Would *You* Address Treatment for This Athlete?

Problem List:

ROM/Flexibility Issues:

Limited Ankle DF
Hypermobility Anterior Shoulder

Needs Change of **Movement Patterns!**

More Upright trunk with Snatch/Overhead Squat

Needs Shoulder Stability/ER with Overhead Pressing/OH Squat



Treatment Plan: Case 3

Step 1: Pain Relief for Anterior Shoulder

- Soft Tissue Mobilization
- Teach self-mobilization techniques, such as foam rolling or lacrosse ball to anterior and posterior shoulder/upper traps (review, as this patient is already doing this)
- **Supine Posterior GH Glide**
- Kinesiotape for posterior GH glide/ posture assist

Step 2: Prevent From Recurring

1. Ankle Joint ROM
2. Overhead Shoulder Movement Quality
3. Training/Volume Issues



Treatment Plan: Case 3

Step 2: Prevent from Recurring

Ankle Dorsiflexion- get torso more upright
Talocrural Joint Mobs (posterior to improve DF)
Posterior Ankle Glide (Banded)

Shoulder Stability-cue "biceps up"
Kettlebell Screwdriver in Supine or Sidelying
Deep Squat Overhead Reach
Banded Pull-aparts to Overhead Squat
Banded Wall Slides (FL)

BREAK OUT



Load Management/Modifications

Shoulder Pain and Pressing

- Load: Decrease Weight on the Bar
- Tempo: Eccentrics
- Variation: Kettlebells (bottoms-up), Dumbbell Press, Grip direction
- Modify: hand grip width



Case 4 PT Eval: Back Pain Deadlifting, Squatting

William: 36 yo male Olympic Lifter reporting hip and back tightness that bothers him during and after training deadlifts, squats, cleans, snatches; Attributes to "getting older, it's all downhill after 30!"

Aggravators: DL, Squat, full cleans, full snatch sleeping on back, walking his dogs, end of the day after long periods of standing

Ease: Good warmup, foam rolling, power clean, power snatch

Social: Construction contractor, in the field for 30h/wk

Wellness: sleeps 7.5-8h/night, nutrition: 3 big meals per day; high protein, high carb, high vegetable; Stress: moderate as wife is in between jobs

Movement Assessment:

- Squat: lumbar hyperextension
- Deadlift: finishes with opened chest
- Snatch/Clean: spine dominant second pull, hips closed, anteriorly tilted
- SL squat: poor control
- Bridge: Feels spinal erectors

Table Assessment:

- Discomfort with extension
- QL/erectors TTP, hypertrophied
- Small glute development compared to quads
- (+) Thomas Test



How Would You Address This Athlete?

Problem List:

ROM/Flexibility Issues:
Limited Hip Flexor Flexibility

Needs Change of **Movement Patterns**:
Needs more glute activation to promote hip extension rather than lumbar
paraspinals/QL



Treatment Plan: Case 4

Step 1: Pain Relief for Lumbar Strain

- Soft Tissue Mobilization to Lumbar Paraspinals, QL, Glutes, even Hamstrings if needed
- Myofascial Decompression ("cupping") to Lumbar Paraspinals/QL
- MFD with movement: Lumbar FL
- Lumbar FL Stretch/Decompression with Band (standing or on bench)

Step 2: Prevent From Recurring

1. Joint ROM
2. Movement Quality
3. Training/Volume Issues (discussed in depth later)

BREAK OUT



Treatment Plan: Case 4

Step 2: Prevent from Recurring

- Hip Flexor Stretch
Thomas Stretch
Kneeling Hip Flexor Stretch with Anterior Glide (Banded)

Glute activation to promote hip EXT rather than Back EXT:
SL Bridge with knee to chest
Posterior Pelvic Tilt- supine, standing

BREAK OUT



Load Management/Modifications

Back Pain Deadlifting and Squatting

- Load: Decrease Weight on the Bar, Decrease Sets/Reps
- Tempo: Squat eccentrics, Pause Squats, Isometrics Holds
- ROM: Box Squat, Half/Quarter Squat
- Variation: Front Sq, Back Sq, OHS, Goblet Sq, Single Arm Goblet Sq, SL Squat, SL Box Squat, Split Squat
- Modification: Front Squats instead of Back Squats
- Modification: High Bar vs Low Bar during Back Squat



Barbell Skills: Review & Practice

Clean & Jerk

Snatch



CrossFit



SCREEN	TEST
Cervical	-Standing neck extension
Thoracic	-Seated thoracic extension
Lumbar	-Standing forward bend -Supine SLR
Shoulder	-Standing functional IR/ER -Standing PVC high pull -Supine shoulder flexion
Elbow	-Standing elbow flexion -Standing elbow extension
Wrist	-Standing prayer position
Hip	-Squat -Split squat (hands OH) -Standing hip rotation -Standing multi-segmental extension (DL) -Supine knees to chest -Supine hip IR -Supine Thomas test (SL)
Knee	-Supine heel to buttock -Supine TKE
Ankle	-Half kneeling knee to wall



-Full
-Hang (high, above, below, mid-shin)
-Power (2", 4", 6")

Course Objectives

- **Evaluate and analyze barbell lifts** including: deadlifts, squat variations, and Olympic lifts, and provide feedback of biomechanical inefficiencies.
- Provide specific **modifications to barbell lifts** (deadlifts, squat variations, and Olympic lifts) for individuals experiencing pain based on clinical presentation and barbell evaluation and analysis.
- Demonstrate the ability to **provide manual therapy interventions** based on clinical reasoning, evaluation, and analysis of barbell lifts.
- Demonstrate novice **competency and comprehension of barbell lifts**, their variations, and derivatives.
- Develop **evidence-informed short and long term plan of care programs** consisting of: manual therapy, corrective exercises, and modifications and progressions of barbell lifts, based on patient goals and soft tissue healing timelines.



Reflect...

- What is your biggest takeaway from this course?*
- Are you interested in practicing the Olympic lifts?*
- What new perspectives do you attribute to being here?*
- How will you market your new knowledge (Locally? Within clinic?)*



Contact Information

- Dr. Chris Garcia
- www.DrChrisGarcia.com
 - Instagram & Facebook: @ChrisGarciaDPT
- Sports Performance Physical Therapy
- www.SportsPerformancePT.com
 - Instagram & Facebook: @SportsPerformancePT
- Chris@DrChrisGarcia.com



References

1. Schoenfeld BJ. Squatting kinematics and kinetics and their application to exercise performance. *J Strength Cond Res.* 2010;24(12):3497-3506.

2. Escamilla RF, Flesig GS, Lowry TM, Barrentine SW, Andrews JR. A three-dimensional biomechanical analysis of the squat during varying stance widths. *Med Sci Sports Exerc.* 2001;33(6):984-998.

3. Neumann DA. Kinesiology of the hip: a focus on muscular actions. *J Orthop Sports Phys Ther.* 2010;40(2):8294.

4. Dostal WT, Soderberg GL, Andrews JG. Actions of hip muscles. *Phys Ther.* 1988;68(3):351-61.

5. Donnelly DV, Berg WP, Fiske DM. The effect of the direction of gaze on the kinematics of the squat exercise. *J Strength Cond Res.* 2006;20(1):145-150.

6. Li G, DeFriele LE, Rubesh HE, Gil TJ. In vivo kinematics of the ACL during weight bearing knee flexion. *J Orthop Res.* 2005;23(2):340-344.

7. Nagura T, Dyrby CO, Alexander EJ, Andriacchi TP. Mechanical loads at the knee joint during deep flexion. *J Orthop Res.* 2002;20(4):881-886.

8. Gullett JC, Tittman MD, Gutierrez GM, Chow JW. A biomechanical comparison of back and front squats in healthy trained individuals. *J Strength Cond Res.* 2009;23(1):284-292.

9. Eltoukhy M, Travasico F, Adfour S, Elmasy S, Heredia-Vargas H, Signorile J. Examination of a lumbar spine biomechanical model for assessing axial compression, shear, and bending moment using selected olympic lifts. *J Orthop.* 2015;13(2):210-219.

10. Cholewicki J, McGill SM, Norman RW. Lumbar spine loads during the lifting of extremely heavy weights. *Med Sci Sports Exerc.* 1991;23(10):1179-1186.

11. Stuart MJ, Maglian DA, Lutz GE, Growny ES, An KN. Comparison of intersegmental tibiofemoral joint forces and muscle activity during various closed kinetic chain exercises. *Am J Sports Med.* 1996;24(6):792-799.

12. Glasbrook DJ, Helms ER, Brown SR, Storey AG. A review of the biomechanical differences between the high-bar and low-bar back squat. *J Strength Cond Res.* 2017;31(8):2618-2684.

13. Escamilla RF, Flesig GS, Zheng N, Lander JE, et al. Effects of technique variations on knee biomechanics during the squat and leg press. *Med Sci Sports Exerc.* 2001;33(6):1552-1556.

