Proximal hamstring injury: a pain in the butt
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Hamstring muscle complex
- Semimembranosus
- Semitendinosus
- Biceps femoris

Proximal HS muscle complex: origin
- Semimembranosus tendon – most lateral
- Conjoint tendon of semitendinosus/long head of biceps femoris

Hamstring strains
- Common injury for many sports
  - Track, football, water skiing, dance, rugby
- Accounts for 25-30% of all muscle strains
- Typically myotendinous injuries
- Often involves long head of biceps femoris
  (Garrett et al, 2000)

Classification of proximal HS injuries:
- Type 1: osseous avulsions
- Type 2: musculotendinous junction
- Type 3: incomplete tendon avulsion from bone
- Type 4: complete tendon avulsion with minimal retraction of tendon ends
- Type 5: complete avulsion with retraction of tendon ends
  - 5a: no associated sciatic nerve scarring
  - 5b: associated with sciatic nerve tethering
  (Wood et al, 2008)

Mechanisms of injury
- sprinting/high speed running
- Extreme stretch
- Extreme and forceful stretch

Sprinting/high speed running
- Most common in full stride or with attempt to overstride
- Usually late swing/early stance phase of gait
- Significant amount of eccentric firing of HS
- Commonly long head of biceps femoris
  (Linklater et al, 2010)

Extreme stretch
- Involves hip flexion with associated knee extension
- Commonly involves proximal MTJ of semimembranosus
- May be slow or fast movement
  (Linklater et al, 2010)

Extreme and forceful stretch
- Most commonly described in association with water skiing injuries
• Commonly associated with proximal HS tendon avulsions  
  (Linklater et al, 2010)

**Extreme/forceful stretch**

**Clinical presentation**
• Sudden onset of posterior thigh pain
• Often unable to continue activity
• Often unable to tolerate WB on involved side immediately after injury

**Goals in physical examination**
• Determine severity of injury
• Differentially diagnose posterior thigh pain
  o Distinguish true HS strain from other possible sources of posterior thigh pain
• Identify biomechanical deficits in adjacent structures that may contribute to injury/pain
• Assist in prognosis

**Physical examination: palpation**
• Identify distance from ischial tuberosity to site of maximum pain on palpation
  o Expected recovery time increases the more proximal the site (the closer the distance)
• May see ecchymosis
• Palpable defect in muscle may be seen/felt with ruptures

**Physical examination: strength**
• Hip extension
  o Knee flexed to 90°
  o Knee extended to 0°
• Knee flexion (prone)
  o Knee 90° flexion
  o Knee 15° flexion
  o Tibia neutral/ER/IR
  ✷ If involved side strength is 30% or less than uninvolved and ecchymosis is present, may be indicative of acute proximal HS rupture  
  (Ali and Leland, 2012)

**Physical examination: range of motion**
• Knee active extension test
  o Deficit in knee AROM extension helps to grade severity of injury and assist in prognosis for recovery time(Malliaropoulos et al, 2010)

**If a HS rupture is suspected: DI**
• Plain radiographs
  o Minimal value except for avulsion/apophyseal fx
• Ultrasound
  o Scarring may obscure reading
  o Less useful for deep injuries
• MRI
  o Injury CSA proportional to time away from sport
  o Ineffective at predicting re-injury risk  
  (Heiderscheit et al, 2010)
Differential diagnosis of posterior thigh pain/injury

• 83 Australian rules football players with posterior thigh injury – MRI after clinical testing
• Clinical parameters measured
  o Acute versus sudden onset
  o Pain on resisted HS muscle contraction
  o Presence/absence of tenderness to palpation of posterior thigh
• Results:
  o 68 confirmed HS injuries via MRI
  o 12 no HS injury via MRI
  o 3 “other” – glut max/adductor
• 62/68 HS injuries reported sudden onset
• 5/12 no HS injuries reported sudden onset
• All athletes had tenderness in post. Thigh and pain with resisted HS contraction
  (Verrall et al, 2003)

Differential diagnosis: potential mimickers

• Lumbopelvic dysfunction, SI dysfunction, sciatic entrapment (HS Syndrome), other closely
  associated muscle/tendon injury (adductor strain, piriformis, glut. Max)
  (Bruckner and Khan, 2006)

Prognosis: recovery time

• Increased recovery time is associated with:
  o High speed running versus extreme stretch injury
  o Injury to proximal free tendon
  o Proximity of injury to ischial tuberosity
  o Increased CSA of injury based on MRI
  o More than one day needed to walk pain-free following injury
  (Warren et al, 2010; Heiderscheit et al, 2010)

Intrinsic risk factors for HS injuries
  (Engebretsen et al, 2010)

508 soccer players followed for 1 season:
• Low HS strength
• Short HS muscles
• High maximum sprint speed
• Reduced function scores (HaOS)
• Age
• BMI
• History of prior HS injury

Possible physical factors that could contribute to original injury and/or reinjury

• Strength imbalance
  o Lumbopelvic
  o Hamstrings: Quadriceps
• Neuromuscular control
• Flexibility
• Musculotendon scarring
Strength imbalance

- Lumbopelvic
  - If gluteal weakness is present, the HS muscles may compensate by shortening (becoming tighter) to contribute to SI joint mobility (due to common attachments on ischial tuberosity and sacrotuberous ligament)

- HS:Quads Ratio
  - Strength imbalance (>20%) between eccentric HS (30°/sec) and concentric quads (240°/sec) resulted in 4-fold increase in risk ratio for HS injury (Crosier et al, 2008)
  - Adding eccentric HS strength ex into training for elite level soccer players has been shown to reduce the incidence of HS strain injuries (Arnason et al, 2008)

Musculotendon scarring

- Optimum length for active tension (peak torque) is shorter when comparing previously injured HS to non-injured (40.9° versus 29.8°)
- One reason for this may be scar tissue formation (scar tissue stiffness>contractile tissue stiffness and may alter muscle/tendon contraction mechanics)
- Strength of tissue with scarring present

Neuromuscular control

- Altered muscle activation noted via EMG following a HS injury
  - Shift from bilateral stance to SL stance
    - Biceps femoris and medial HS fired significantly earlier in HS injured group versus controls (Sole, 2011)
- Interplay between firing/stretch of hip flexors (iliopsoas) and contralateral HS
  - Firing of iliopsoas in high speed running induces a stretch on the contralateral HS (Chumanov et al, 2007)

Flexibility

- Quadriceps
  - Decreased quads flexibility is a risk factor for HS strain injury (Gabbe et al, 2005)
- Hip flexors (iliopsoas)
  - Tightness here increases stretch to contralateral HS
  - Tightness in antagonist muscle group (lower crossed syndrome???)
- Hamstrings
  - Inclusion of HS flexibility into exercise program has not been shown to reduce HS injury incidence(Arnason et al, 2008; Brooks et al, 2006) ???

Rehabilitation/treatment once HS injury occurs

- Rehabilitation should have 2 main concerns:
  - Return to sport/PLOF
  - Avoiding reinjury

- If a partial rupture/rupture is suspected, refer for further evaluation as surgery may be the
best option (Harris et al, 2011)

**Conservative treatment:**
what to emphasize/where to start????

- Early protection
- Scar tissue management
- Stretching???
- Strengthening???
- Neuromuscular control
- Lumbopelvic biomechanics

Sherry and Best, *JOSPT*, 2004

- Prospective randomized comparison of 2 rehab programs
- Methods:
  - 24 athletes with HS strain randomly assigned to one of 2 groups:
    - Static stretching/isolated progressive HS resistance exercises and ice (STST)
    - Progressive agility, trunk stabilization exercise and icing (PATS)
- Evaluated
  - time to return to sport
  - Reinjury rate during 1st 2 weeks and first year after return to sport

**STST Group:**
- Stationary bike
- Supine and standing HS stretches
- C/R HS stretching
- Sub-max HS isometric ex
- Prone leg curls
- Hip extension in standing with knee straight (Tband for resistance)
- NWB “foot catches”

**PATS Group:**
- Sidestepping
- Grapevine stepping
- Steps FW/BW over a line while moving sideways
- SLS (eyes open/closed)
- Prone plank
- Supine plank
- SL plank
- SLS windmill touches
- Push-up stabilization with trunk rotation
- Fast feet in place (ft only a few inches off ground)

**Progressive agility/stabilization exercises**
**Phase 1**
**Progressive agility/stabilization exercises: Phase 2**
**Results**
• In the first 2 wks after return to sport, reinjury rate was significantly greater in the STST group \((p = 0.003)\) than the PATS group
• After one year of return to sports, reinjury rate was significantly greater in the STST group than the PATS group \((p = 0.006)\)

Heiderscheit et al, JOSPT, 2010

• Clinical commentary synopsis:
  - *Hamstring strain injuries: recommendations for diagnosis, rehabilitation and injury prevention*
  - Proposed guide to rehabilitation of HS strain injuries (grade I and II) based on “current available best evidence”
  - 3 phases with specific treatment goals and progression criteria for phase advancement and return to sport

**Phase 1**
- **Goals**:
  - Protect scar development
  - Minimize atrophy
- **Protection**:
  - Avoid excessive active or passive lengthening of the HS

**Phase 1 exercises**
- Stationary bike x10 min
- Side-step, 3x1min, low/mod intensity, pain-free
- Grapevine, 3x1min, low/mod intensity, pain-free
- Fast feet stepping in place, 2x1min
- Prone plank, 5x10sec
- Side plank, 5x10sec
- Supine bent knee bridge, 10x5sec
- SL balance, progress to eyes closed, 4x20sec

**Criteria to progress to phase 2**
- Normal walking stride without pain
- Very low speed jog without pain
- Pain-free isometric contraction against sub-maximal (50-70%) resistance during prone knee 90° flexion MMT

**Phase 2**
- **Goals**
  - Regain pain-free HS strength (begin midrange and progress to longer length strength)
  - Develop neuromuscular control of trunk/pelvis, gradually increasing speed
- **Protection**
  - Avoid end range lengthening while HS weakness persists

**Phase 2 exercises**
- Stationary bike x10min
- Side shuffle, 3x1min, mod/high intensity, pain-free
- Grapevine jog, 3x1min, mod/high intensity, pain-free
- Boxer shuffle, 2x1min, low/mod intensity, pain-free
• Rotating plank, 2x10 reps, 5 sec hold ea
• Supine bent knee bridge walk-out, 3x10
• SLS windmill touch, 4x8 reps/arm on each leg (no wgt)
• Lunge walk with trunk rotation, opposite hand/toe touch, 2x10 steps/limb
• SLS balance with trunk FW lean and opposite hip extension, 5x10 sec/limb

**Phase 2 exercise video**

**Criteria for progression to phase 3**
• Full HS strength (5/5) with prone 90° knee flexion MMT – pain-free
• Pain-free FW and BW jog with moderate intensity

**Phase 3**

**Goals**
- Symptom-free during all activities
- Normal concentric/eccentric HS strength through full ROM
- Improve neuromuscular control of trunk/pelvis
- Integrate postural control into sport-specific movements

**Protection**
- Avoid full intensity if pain/tightness/stiffness present

**Phase 3 exercises**
• Stationary bike x10 min
• Side shuffle, 3x1 min, mod/high intensity, pain-free
• Grapevine jog, 3x1 min, mod/high intensity, pain-free
• Boxer shuffle, 2x1 min, mod/high intensity, pain-free
• Skips, gradually increasing knee-height, pain-free
• FW/BW accelerations, 3x1 min, 5 to 10 to
• 20m Rotating plank with wgt, 2x10 reps, 5 sec hold ea
• Supine, SL chair bridge, 3x15 reps, slow to fast speed
• SLS windmill touch, 4x8 reps/arm on each leg (with wgt)
• Lunge walk with trunk rotation, opposite hand/toe touch with wgt, 2x10 steps/limb
• Sport-specific drills that incorporate postural control and increasing speed

**Phase 3 exercise video**

**Criteria for return to sport**
• Full-strength without pain
  - 4 consecutive reps maximal effort strength test in each prone knee flexion position (90° and 15°)
  - Less than 5% bilat deficit eccentric HS (30°/sec):concentric quads (240°/sec)
• Full ROM pain-free
• Replication of sport-specific movements near maximal speed, pain-free
Role of more aggressive plyometrics in hamstring rehabilitation

- Retrospective case series (48 athletes)
- Only applied to grade I and II strains
- Main components
  - Brief immobilization (24 hrs)
  - Early initiation of running/isokinetic/plyometric exercises
  - Progressive static HS stretching
    - Kilcoyne et al, 2011
- 1st 24 hrs: compression via ace wrap/pad and immobilization with knee immobilizer
- Day 2:
  - Jog till fatigued
  - Static, elevated HS stretch, 60-90 sec hold between each drill, pain-free
  - Ice after exercise
    - Kilcoyne et al, 2011
- Day 3:
  - Add in run program (butt kickers, cariocas, cone drills –retro runs)
  - Add in plyometrics (kangaroo jumps, tuck jumps, bounding)
- Day 7
  - Eccentric exercises prone off plinth, 2x 10 reps
  - Isokinetic training
    - High speed: 300/300°/sec 90 sec, rest 90 sec
    - Power/speed: 90/90, 180/180, 240/240, 120/120°/sec (15 sec ea), then 300/300°/sec till burnout

Kilcoyne et al exercise video

- Kilcoyne et al, 2011:
- Results:
  - No significant change/improvement in time to return to sport compared with other data/studies
  - Incidence of re-injury was 6.2% at 6 month follow-up
- Considerations:
  - If your athlete needs more plyometrics for their sport, may add these components to their rehab sooner versus later

**Grade III and IV injuries:**
How to manage???

- Surgical repair versus conservative non-surgical treatment for partial ruptures or complete ruptures/avulsions
  - Single tendon tear versus multi-tendon tear
  - Amount of retraction with a tear
- Surgical versus non-surgical treatment outcomes
  - Patient satisfaction
  - Hamstring function/strength
  - ***return to sport***
Surgical versus Non-surgical

- Surgical repair demonstrated better
  - Subjective outcomes
  - Strength/endurance
  - Rate of return to pre-injury level of sport (82% versus 14% at final follow-up)
    \((p<0.05)\)

Acute versus chronic repair

- Acute repair (<4 wks post injury) demonstrated better
  - Subjective outcomes
  - Patient satisfaction
  - Pain relief
  - Strength/endurance
  - Rate of return to pre-injury level of sport
    \((p<0.001)\)
  - Reduced risk of complications
  - Re-rupture rate
    \((p<0.05)\)

Take home message

- If a rupture is confirmed surgical repair may be the best choice especially if return to pre-injury level of sport is critical
- Act quickly to determine if a rupture is present as repair of a chronic injury (> 4 wks) has improved outcomes versus non-surgical repair BUT not to the same degree as acute repair
  - Chronic repairs often require sciatic neurolysis, lysis of adhesions, distal fractional lengthening, possible need of allograft interposition

Other reasons to consider surgical treatment

- Failed conservative treatment
- Hamstring syndrome

Surgical repair

Primary repair

- Torn tendon stump mobilized
- Repair of tendon stump to ischium with suture anchors
- Sciatic neurolysis performed if needed (32% in chronic, 18% in acute – Harris et al, 2011)

Allograft/Autograft

- Typically used for failed or chronic injuries where a large defect between distally retracted tendons and ischial tuberosity prevents primary repair
  - Fascia lata autograft
    \((\text{Lempainen et al, 2007})\)
  - Achilles tendon allograft
    \((\text{Folsom and Larson, 2008})\)

Post-op rehabilitation considerations

- Primary versus allo/autograft repair
- Avoid stretching of HS beyond \(90^0\) SLR
• Bracing to protect the repair

Post-op rehab protocol: Primary repair
(Ali and Leland, 2012)

• General considerations
  o Weight bearing
    ✖ 0-2 weeks: TTWB (10% of wgt)
    ✖ 2-4 weeks: 25% WB
    ✖ 4-6 weeks: 50% WB
    ✖ 6+ weeks: WBAT
  o Hip brace (set at neutral abduction)
    ✖ 0-2 weeks: 0-30°
    ✖ 2-4 weeks: 0-45°
    ✖ 4-6 weeks: 0-60°
    ✖ 6 weeks: d/c brace

Post-op rehab protocol: Primary repair
(Ali and Leland, 2012)

• Week 0
  o Ankle pumps, supine quad sets with SLR in limit of brace

• Week 2
  o Begin PT
    o GENTLE PROM hip/knee (pain-free) – no combo hip flexion/knee ext
    o Submax isometric hip abd/add
    o STM post thigh and patellar mobs

• Week 4
  o Active SLR out of brace without HS pain/pulling
  o Begin lumbopelvic stab ex
  o Calf stretching/ankle strengthening with hip in extension
  o Passive ONLY hip ext (no active HS!!)

• Week 6
  o Normal gait training
  o Active HS exercises (gravity only – no added wgt)
  o Core pelvic strength training
  o Closed chain exercises
  o SL proprioception exercises
  o Isotonic exercise in mid-range
  o Quad strengthening

Post-op rehab protocol: Primary repair
(Ali and Leland, 2012)

• Month 2
  o Slowly add resistance to HS ex as tol
  o Advance dynamic training (mini-squats, mini-lunges, resisted side stepping, grapevine, etc.)
  o Stationary bike – no resistance once 90° hip flexion
- **Month 3**
  - Begin light jogging
  - Progress with strengthening HS/gluts/quads
- **Month 4-5**
  - ***may begin isokinetic testing at month 4 to help guide rehab from this point***
  - Advance jogging but still no aggressive acceleration
  - Agility progression
  - Sport specific exercises
  - Begin plyometric exercises
- **Month 6-9**
  - Return to full activity/sports once patient demos full contralateral leg strength and endurance levels

**Main variation on primary repair rehabilitation**
Bracing – is knee flexion part of protection?
(Sallay et al, 2008)

- LE protected for 4-6 wks in a hip-leg harness
- Length of time dependent on tissue/repair quality, tension at repair site and pt age
  (Konan and Haddad, 2010)

- 0-2 wks: 90° knee flexion
- 2-4 wks: 60° knee flexion
- 4-6 wks: 30° knee flexion (begin TTWB)
- 7+ wks: d/c brace (WBAT)

**Post-op rehab protocol: achilles allograft**
(Kirkland et al, 2008)

- **Phase 1 (weeks 0-4)**
  - In combo hip spica/bledsoe brace with neutral hip and 30-45° knee flexion (on crutches, WBAT)
  - Patellar mobilization
  - Isometric quads and sub-max isometric HS sets
  - Gentle lumbopelvic stabilization (abdominal bracing)
  - STM posterior thigh
  - Ice prn
  - By week 2:
    - Isometric hip abd/add
    - Calf stretching with hip in neutral
- **Phase 2 (weeks 4-6)**
  - Progress brace to 0° knee ext, still emph. short stride length
  - Single and double-limb balance and proprioception exercises
  - SL hip abd/add
  - Lumbopelvic stabilization exercises (bridging, prone plank, SL plank – add movement to stab)

**Post-op rehab protocol: achilles allograft**
(Kirkland et al, 2008)
Phase 3 (weeks 6-12)
  - d/c brace, wean from crutches and emphasize normal gait stride length
  - Lumbopelvic stability exercises progress to less stable surfaces
  - WB exercises (lateral stepping, mini-squats, mini-lunges, resisted side-stepping, grape-vines, etc.)
  - Stationary bike
  - Aquatic therapy

Post-op rehab protocol: achilles allograft
  (Kirkland et al, 2008)

Phase 4 ((week 12- return to sport)
  - Emphasize eccentric control of HS
  - Beginning running (straight-plane and progress with multi-planar agility activities)
  - Agility progression (single to multi-planar)
  - Plyometric progression
  - Sport specific drills

Post-op rehab protocol with fascia lata autograft
  (Lempainen et al, 2007)

- More of a salvation surgery (this case series of 5 patients – 4 re-ruptures)
- Post-op weeks 0-3: NWB, pt lying in bed with hip/knee flexion approx. 30\(^{\circ}\), sitting avoided
- Post-op weeks 4-6: PWB, begin isometric ex of HS
- Post-op week 6: wean from crutches to FWB, begin light swimming/aquatic exercise within weeks 6-8
- 3 months post-op: may begin stationary bike and progress with time/intensity

Outcomes
- Isokinetic testing at 60\(^{\circ}\)/sec
  - Maximum HS and Quads torque
  - Peak torque ratio HS:Quads
    (Konan and Haddad, 2010; Sallay et al, 2008)

- Vail Sport test
  - Series of activities with resistance of a SportCord
    - SL squat 3 min
    - Lateral bounding 90 sec
    - FW/BW jogging 2 min ea
  - Passing score considered 46/54
    (Steadman Hawkins Clinic/Howard Head Sports Medicine; Garrison et al, 2012)

Key points
- Try to avoid HS injury
- Emphasize lumbopelvic stabilization and agility to help prevent re-injury
- Try to determine early on the extent of injury
- Act quickly if partial/full rupture is suspected!

Thank you!!

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