Dynamic Stabilisation of the Hip & Pelvis
Lesson 1
Introduction

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1

Goal Statement

Optimal control of the hip and pelvis is integral not only to the musculoskeletal health of this local region, but is the cornerstone of lower limb biomechanics. The pelvis also provides a base of support for the spine and upper limb, particularly in weight-bearing tasks.

This course aims to provide participants with information on stability mechanisms of the hip & pelvis, derived from a wide variety of scientific research and over 20 years of clinical experience.

2

Overall Aims

This course aims to:

1. Enhance clinical reasoning, and skills for development of therapeutic exercise for the hip & pelvis
2. Challenge participants to re-examine their own clinical practice in the light of the presented evidence base
3. Stimulate new thought & provide direction for those who may be interested in contributing to the research base that is shaping contemporary clinical practice in this field.

3

Is this course suitable for you?

This course is suitable for anyone involved in the development of exercise programmes for the hip & pelvis, or the management of musculoskeletal pain of the lower quadrant.

Requirements:

Basic knowledge of anatomy & muscle function in this region

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4

Learning Objectives

Upon completion of this course participants should be able to:

Describe the key elements required for optimal pelvic control

Detail stability mechanisms for the hip & pelvis

Define functional roles of the musculature surrounding the hip and pelvis

Determine the most appropriate exercise approach for an individual using clinical reasoning strategies that consider:

- type and stage of pathology,
- minimisation of negative joint loading, &
- optimisation of muscle recruitment in a manner that is consistent with the natural function of the target muscles

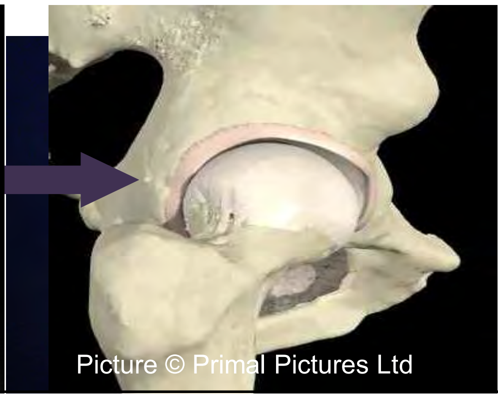
5

Content Outline

Lesson 2: Key elements for pelvic control & intrapelvic stability mechanisms

Lesson 3: Passive & dynamic stability mechanisms of the hip

The role of the dynamic system in controlling negative joint forces such as shear, impingement, & impact loading



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6

Course Content

Lesson 4: Gluteus maximus

Lesson 5: The hip abductors

Lesson 6: The hip flexors

Lesson 7: The hip adductors

Lesson 8: The external rotators

Lesson 9: Summary & Conclusions

Function & Dysfunction

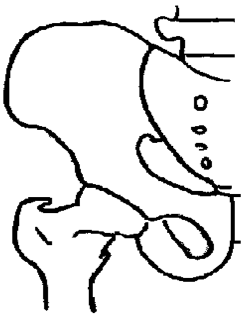
- ❑ Normal function

- ❑ Muscle function & joint pathology
- ❑ Muscle function & unloading

- ❑ Implications for therapeutic exercise

7

Lesson 2
Intrapelvic Stability Mechanisms



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Key elements for pelvic control

1. Optimal intrapelvic stability

2. Optimal control of femoral head in acetabulum

3. Optimal control of pelvis on femur

Optimal static alignment & dynamic control

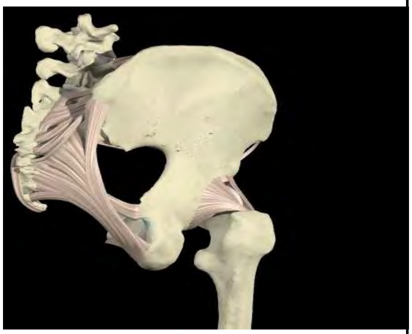
9

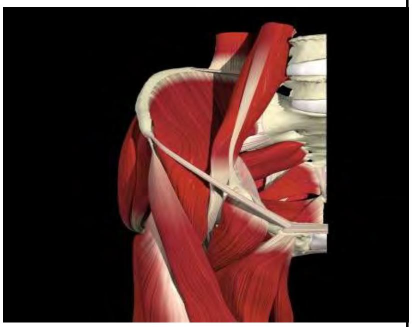
Intrapelvic Stability Systems

Passive Stability Systems

- -Bony Structure
- -Ligamentous System

Active Stability Systems





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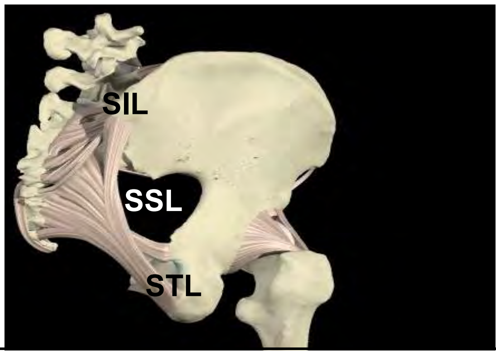
Passive Stability System

Ligaments are not designed to withstand prolonged gravitational load

Cannot continuously load viscoelastic tissue due to the Creep Phenomenon

Ligaments are good for withstanding dynamic load, controlling end range movements and providing proprioceptive feedback



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Active Stability System

Muscular activity is required to withstand prolonged gravitational load.

Continuous low level muscular activity provides 'Self Bracing' for the pelvis

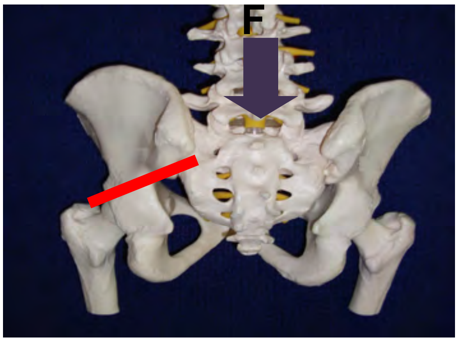
Transversus Abdominis

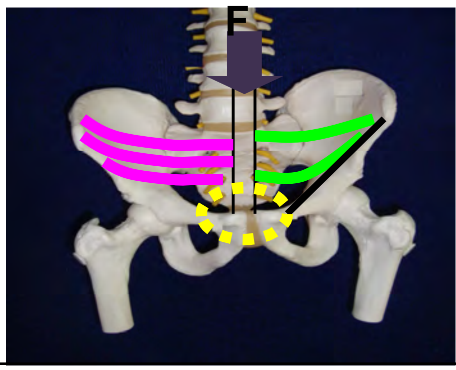
Piriformis

Internal Oblique

Pelvic Floor

Snijders 2006





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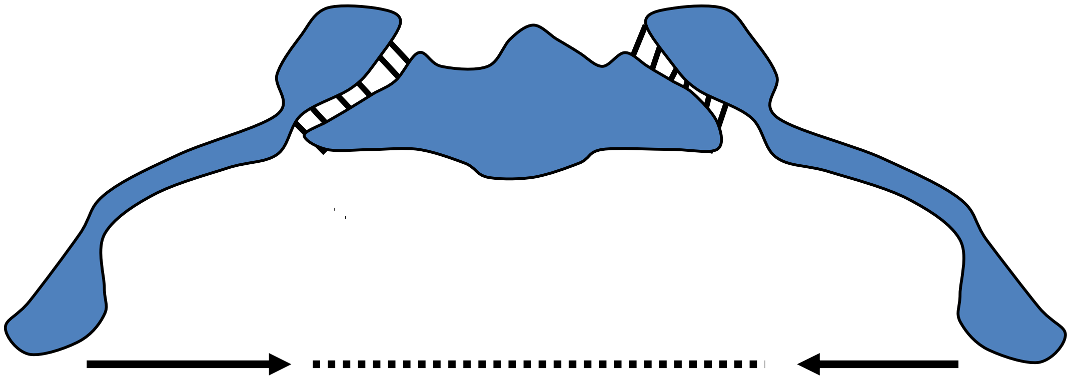
Transversus Abdominis

Isolated contraction of TA significantly reduces SIJ laxity
(Richardson et al 2002)



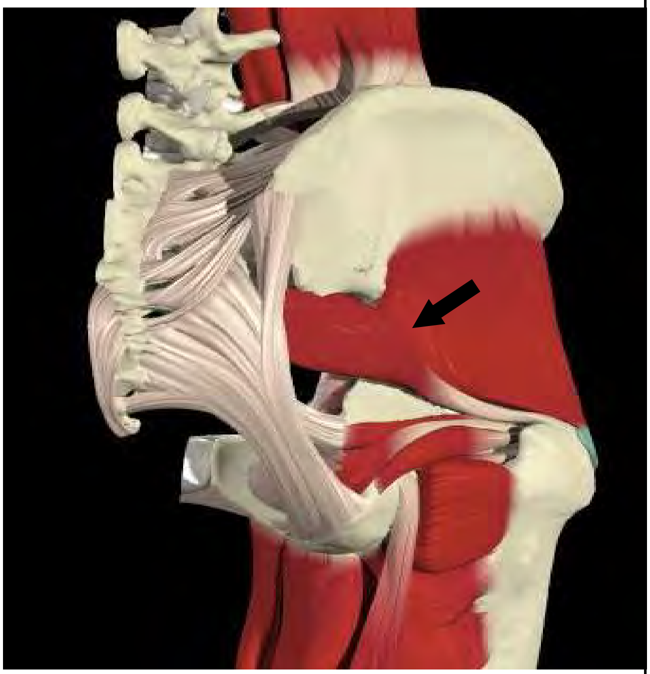
13

Piriformis

Arises from

- anterior surface of sacrum
- gluteal surface of ilium near PSIS
- SIJ capsule
- sacrotuberous ligament variably

Inserts into inner surface of top of GT



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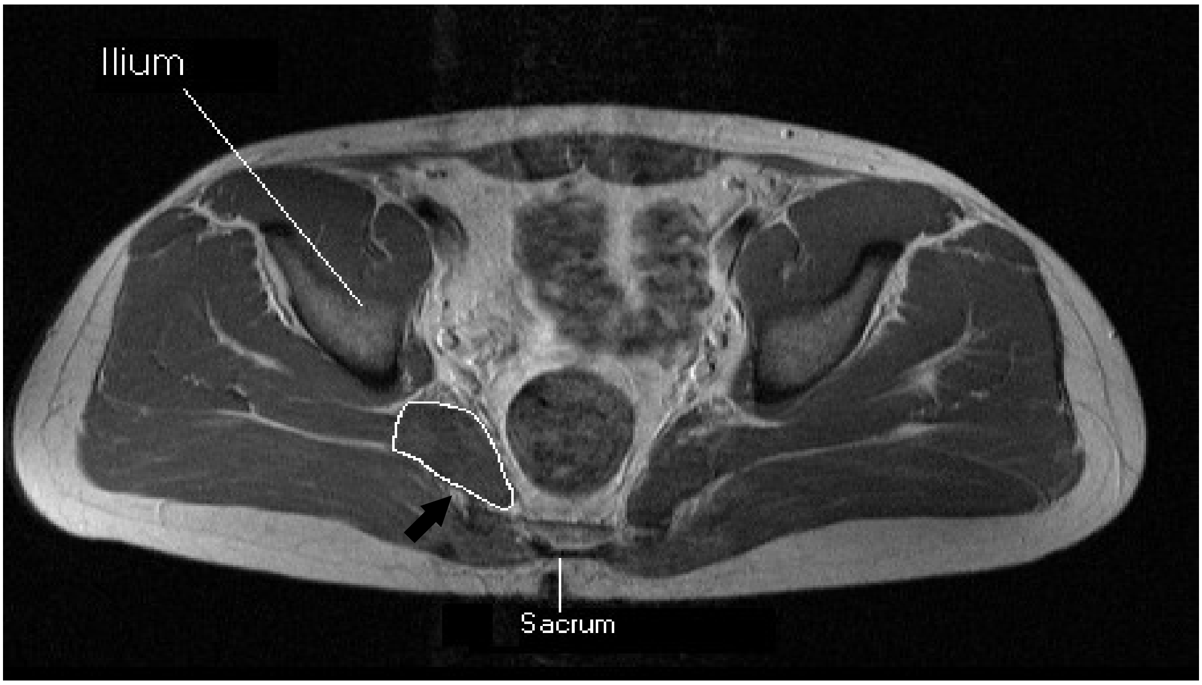
Piriformis



15

Mechanism of action of piriformis

- Attachments to either side of SIJ
- While femurs are stabilised will provide transverse stabilising force across the SIJ's
- High content of collagen – active ligament (Snijders 2006)
- Crossing the legs in sitting increases tension in piriformis, increases SIJ stabilisation and reduces abdominal EMG activity (Snijders 2006)

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Iliacus – an SIJ stabiliser?

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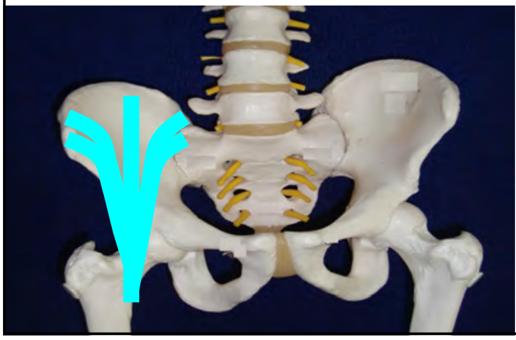


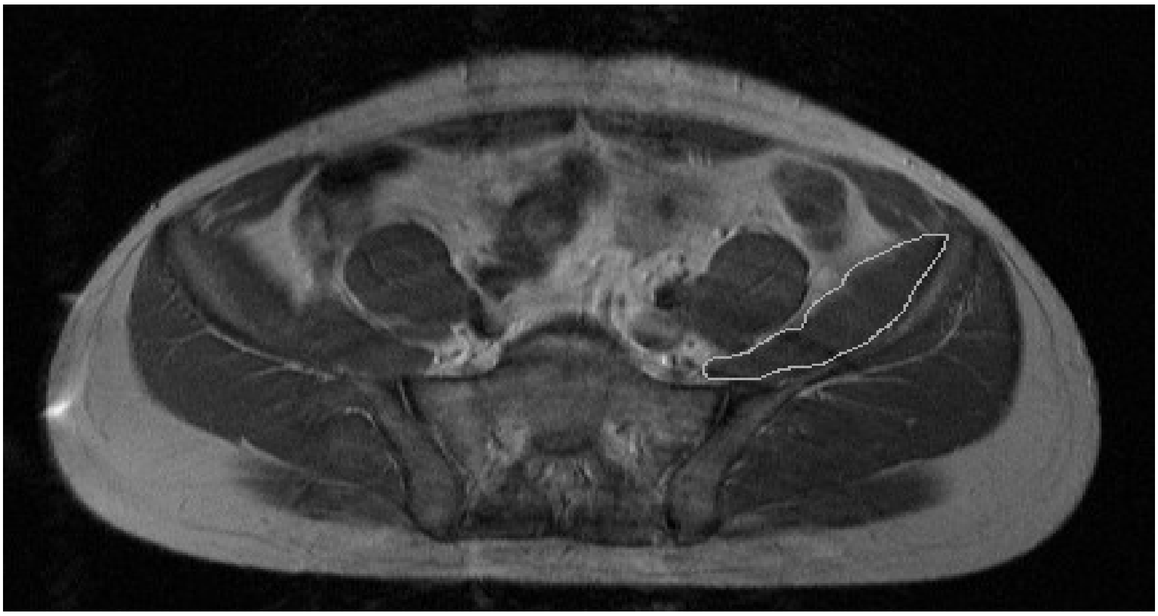
Arises from
- ilium
- ventral sacroiliac & iliolumbar ligaments
- upper surface of lateral portion of sacrum

Iliacus fascia continuous with transversalis fascia
(Williams et al 1989, Grays anatomy)

?? NB end stance phase & early swing

17

Iliacus axial image



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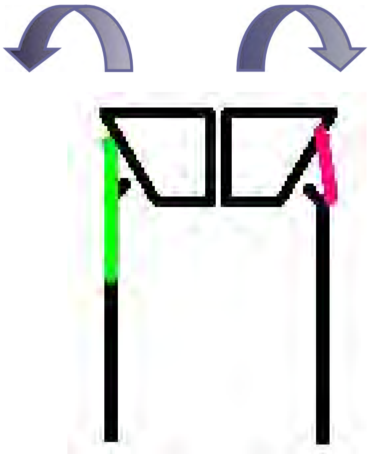
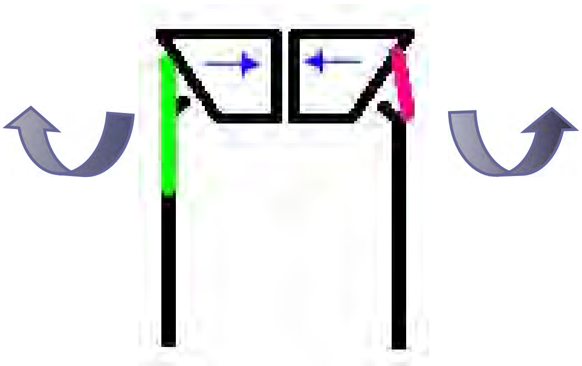
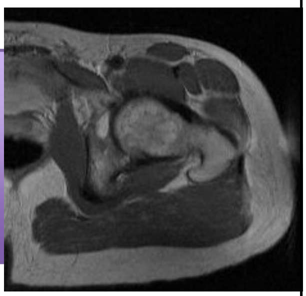
Impact of local muscle function

Intrapelvic stability is required to resist the bifurcating forces of the superficial muscle system





19



Lesson 3
Stability Systems of the Hip Joint

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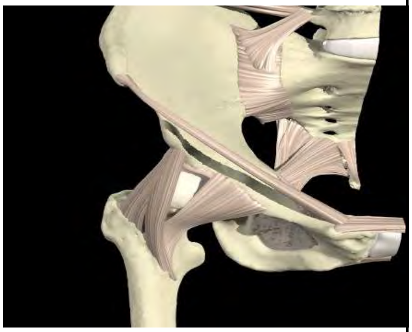
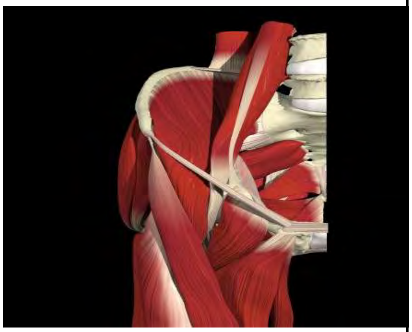
20

Stability Systems of the Hip Joint

Passive Stability Systems



Active Stability Systems



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Passive Stability Mechanisms

Bony structure

Labrum

Negative intracapsular pressure

Capsule & ligaments

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The role of the active system

To help absorb & direct forces imposed on the joint.

Inadequate muscle function/imbalance may contribute to:

Excessive impact loading

Excessive shearing/translation

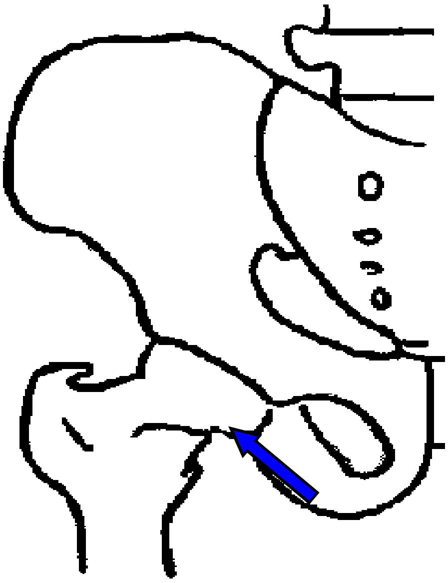
Impingement

↓

Joint damage & migratory patterns of wear

23

Upward & outward migration of HOF



Associated most often with anterior migration

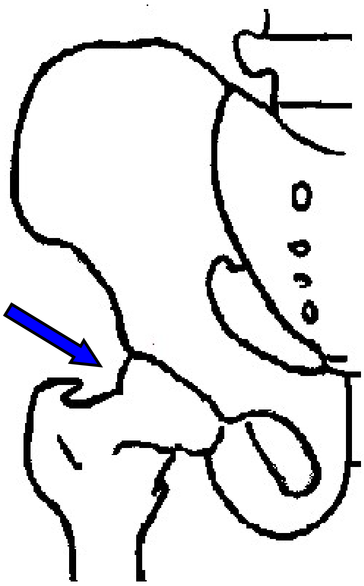
(Cameron & McNab (1975);Mill et al (1993); Hayward et al (1988))

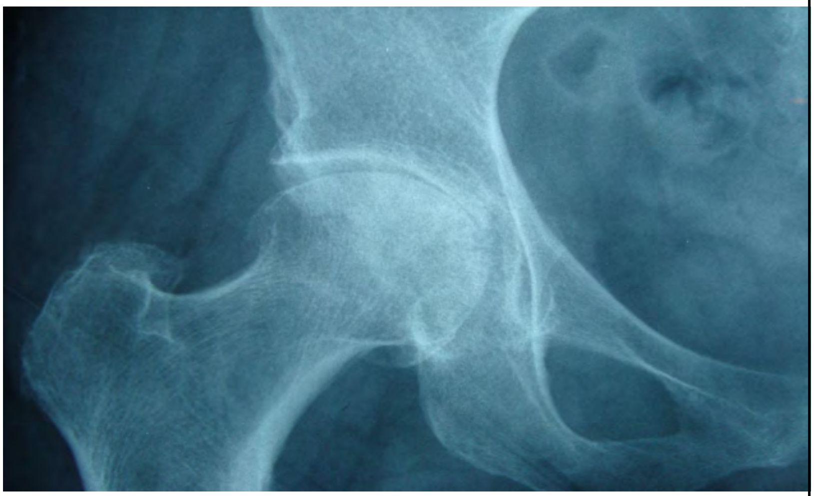
24

Related to postural habits?

25

Downward & medial migration of HOF





Associated most often with posterior migration

(Cameron & McNab (1975);Mill et al (1993); Hayward et al (1988))

26

Active Stability Mechanisms

Layers of muscular control

Important in both the structurally normal, and passively unstable hips

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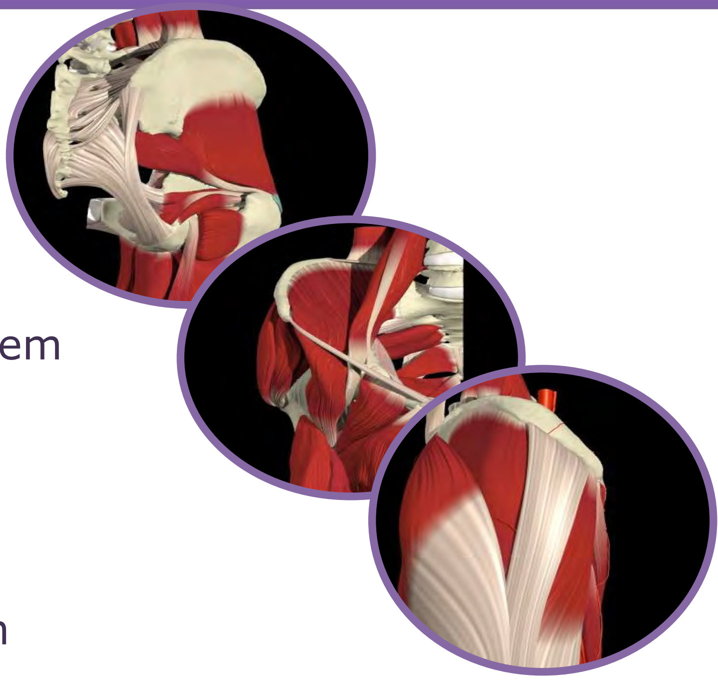
27

Layers of Control

Deep Muscle System

Intermediate Muscle System

Superficial Muscle System



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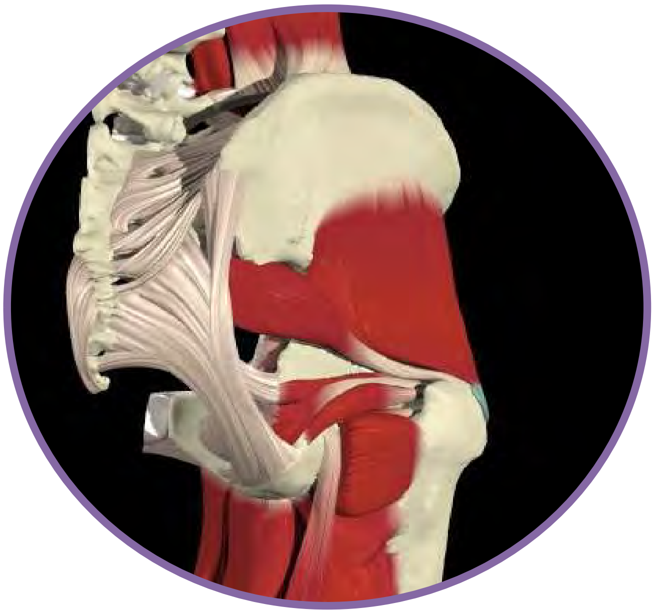
Layers of Control

Deep Muscle System

1° function: Control femoral head in acetabulum

Proprioceptive role, smaller role in torque production



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Layers of Control

Intermediate Muscle System

Significant role in torque production & control of pelvis on femur in WB- lower load function

Secondary stabilisers of femoral head in acetabulum

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Layers of Control

Superficial Muscle System

1° function: Torque production & control of pelvis on femur in WB- high load function

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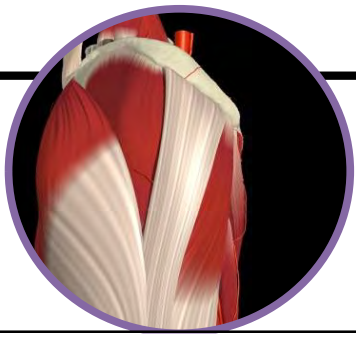
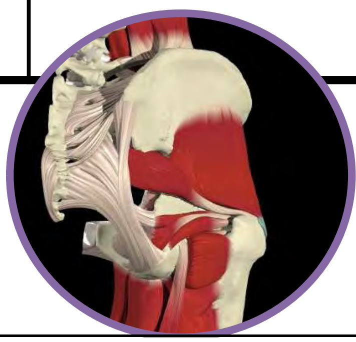
31

Layers of Active Control

SUPERFICIAL	INTERMEDIATE	DEEP
Gluteus Maximus Tensor Fascia Lata Long Adductors Rectus Femoris Sartorius Hamstrings	Gluteus Medius Piriformis Short Adductors Iliopsoas	Iliacus, Iliocapsularis Gluteus Minimus Obt Ext, Int Gamelli Quadratus Femoris





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32

Active Control of Femur & Pelvis

Deep → Intrapelvic stability; Femoral head control

Intermediate → Intrapelvic stability; Femoral head control; Control of pelvis on femur

Superficial → Control of pelvis on femur

Intrapelvic stability

Femoral head control
- Control of translation/shear
- Muscle balance may impact on impingement
- Ensure adequate fem head position for impact

Control of pelvis on femur
- Control of impact loading

33

Reducing Impact Loading

Intermediate & Superficial layers shock absorb during impact – Hip abductors, Hip & Knee extensors

Deep system will have an effect on joint position & stability at time of impact

Hip flexor timing & activation in swing phase has also been shown to have a significant effect on impact forces

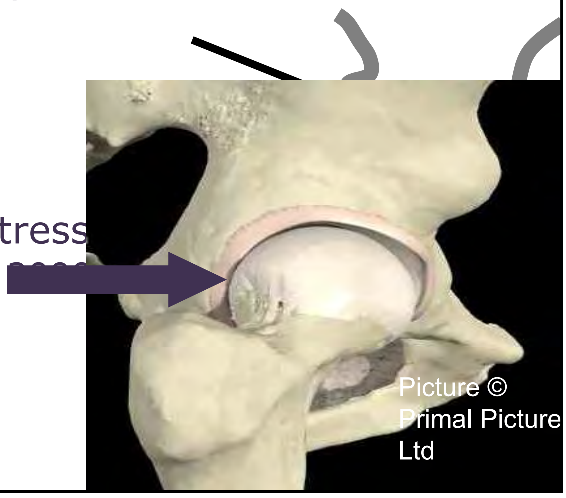
(Gill & O'Connor 2003)

34

Shearing/Translation

May occur secondary to:

- Dysplasia Type 1- 'incongruous hips'
  - Acetabulum shallow, lies more vertical than N & radius of curvature > HOF (Klaue et al 1991)
- Hypermobility
- Labral insufficiency
  - Important anterior restraint
    - With labrum removed shear stress 27-38% higher (Ferguson et al
- Hip extension – anteriorly directed hip forces rapidly increase (Lewis et al 2007,2009)



35

Reducing Shearing/Translation

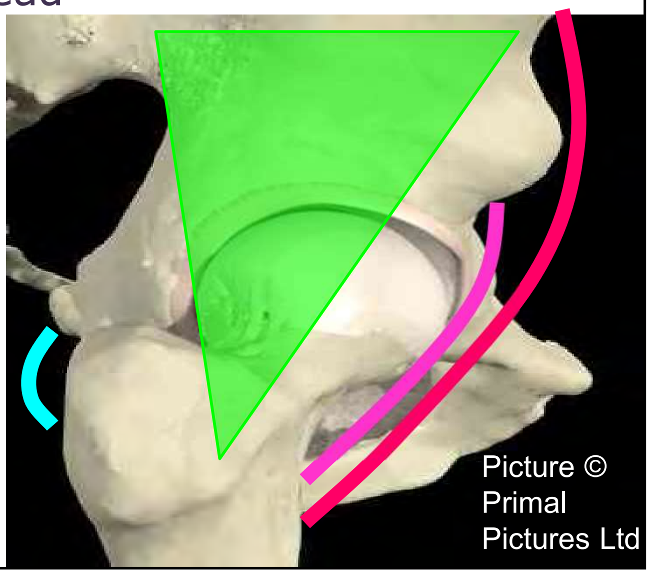
Local control of translatory forces will be best imparted by muscles that attach directly to the joint capsule, or have a direct effect on the femoral head

Iliopsoas

Iliocapsularis

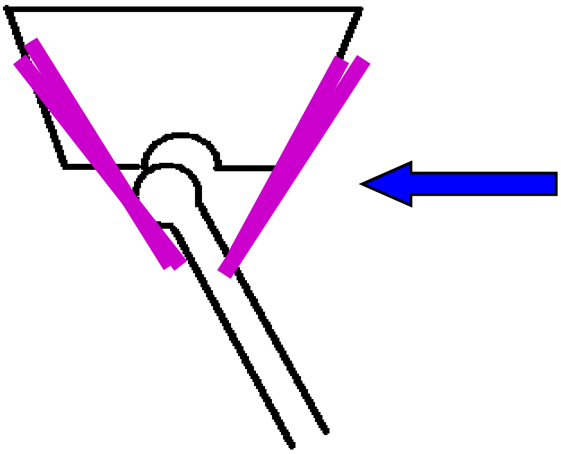
Gluteus Minimus

Deep External Rotators



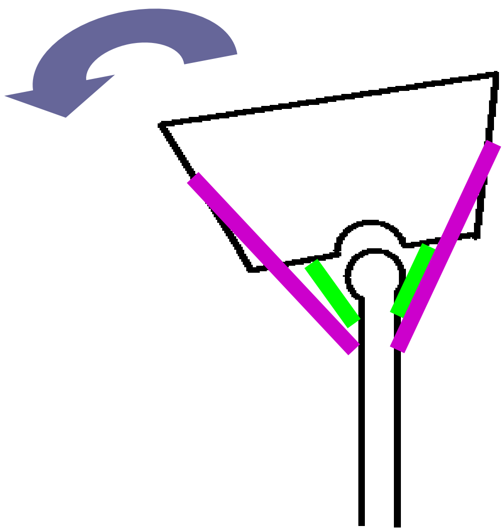
36

Poor function



37

Ideal function

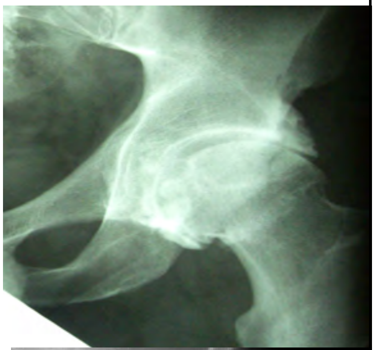


Hip joint stability is necessary for optimal 'pelvic control' as well as for minimising local joint forces

38

Impingement

- Impingement occurs as a normal phenomenon at end of range
- Abnormal bony morphology will result in Femoro-Acetabular Impingement (FAI) earlier in range
- Soft tissue imbalances may impact on impingement, even of a primarily bony nature - most commonly anterior laxity and posterior tightness may result in an anteriorly position HOF – increased risk of anterior impingement.



39

Our role

- Minimise negative joint loading by optimising muscle function, postural habits & movement habits
- Elucidate specific dysfunction in deep, intermediate & superficial musculature
- Provide targeted rehabilitation that addresses specific deficits in a manner consistent with the normal function of the target muscle/s

40

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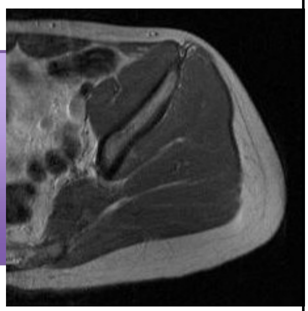
Outline for following lessons

Normal function	Gluteus maximus
Muscle function & joint pathology	The hip abductor synergy
	The hip flexor synergy
Muscle function & unloading	The hip adductor synergy
Implications for therapeutic exercise	Hip external rotators

41

Lesson 4
Gluteus Maximus:
Function & Dysfunction



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42

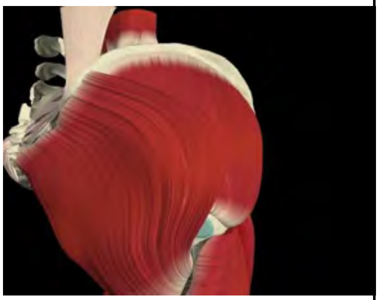
Topics for Discussion

Normal function

Gluteus maximus & joint pathology

Gluteus maximus & unloading

Implications for therapeutic exercise



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Normal function

Upper Glut Max:

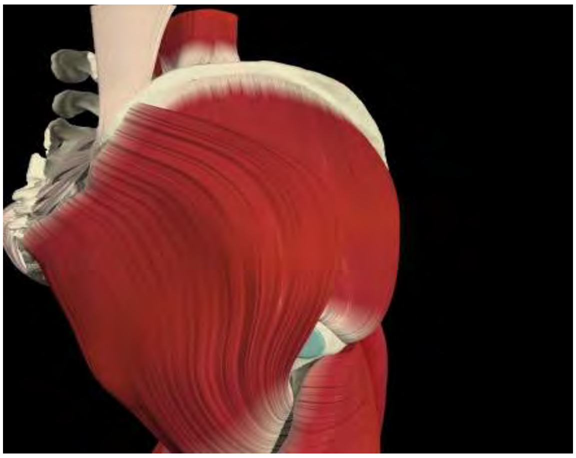
1° Abductor function

Also ER

Lower Glut Max:

1° Extensor function

Also Add & ER



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Glut Max EMG in gait

Adapted from Stern, Pare & Schwarz 1980

45

Glut max in other WB function

Lower glut max will be maximally recruited in a lunge in the trunk forward position (Farrokhi et al 2008)

Always consider gravitational loading in therapeutic exercise prescription

46

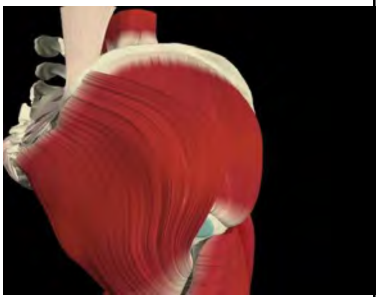
Topics for Discussion

Normal function

Gluteus maximus & joint pathology

Gluteus maximus & unloading

Implications for therapeutic exercise



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Hip Extensor Strength & OA

Rasch et al 2007:

19% less isometric hip extensor strength on the side of pathology in patients with unilateral OA

Arokoski et al 2002:

22% less isometric extensor strength &

13-14% less isokinetic extensor strength on the side with worst hip OA

Use it or lose it! Antalgic unloading will ultimately result in reduced strength in antigravity extensors, but could this loss have preceded the OA?

48

Glut Max Size & Hip OA

Associated with loss of strength, loss of muscle size has been demonstrated in GM in those with hip OA

Rasch et al 2007:

13% smaller in GMax *CSA* on the side of pathology in patients with unilateral OA

Arokoski et al 2002:

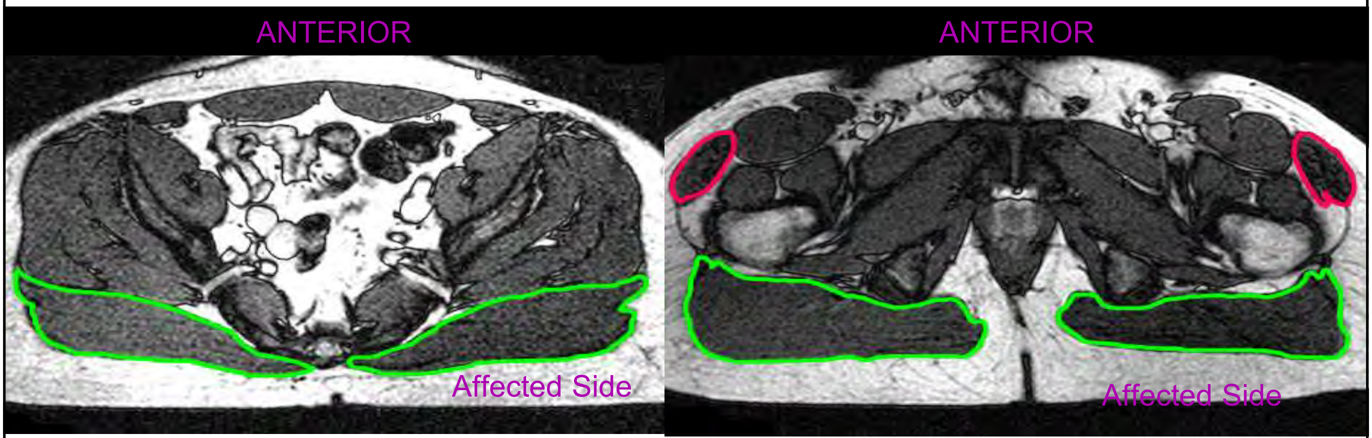
9% smaller lower GMax *CSA* on side of worse pathology in subjects with hip OA

Grimaldi et al 2009:

Measured muscle *volume* of UGM and LGM separately in subjects with unilateral hip OA – mild or advanced, and age & sex matched controls

49

Mild unilateral hip OA



UGM TFL & LGM

Differences between sides were not great enough to reach statistical significance but changes in size and quality observable

Grimaldi et al 2009

50

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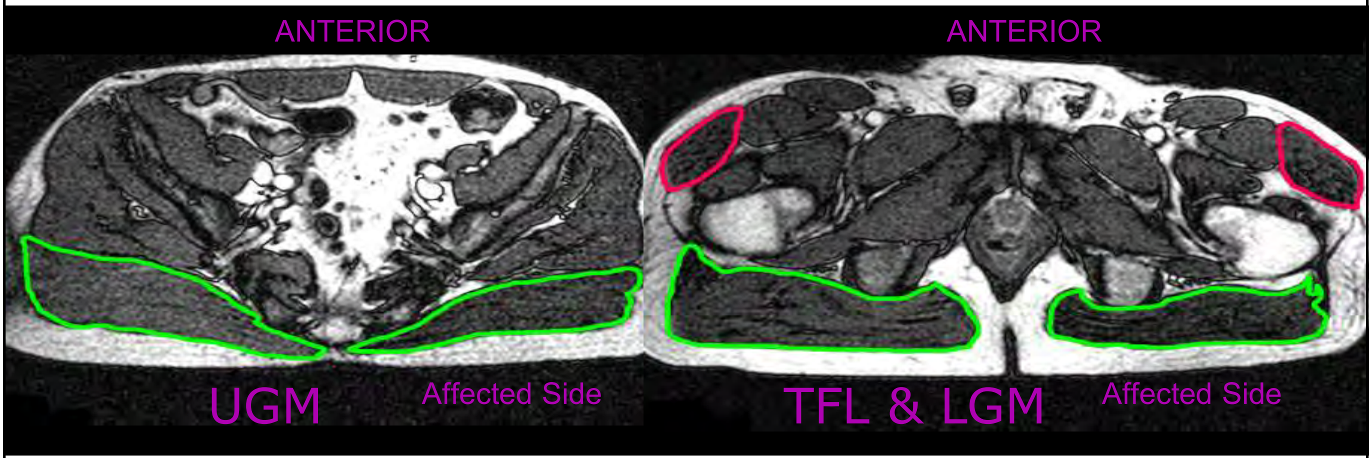
Advanced unilateral hip OA



UGM & LGM: Significantly smaller on affected side (p=0.00;p< 0.05)

UGM significantly larger (mean 24.6%) on <u>unaffected</u> side compared with normal control subjects (p<0.05). TFL NSD in size

Grimaldi et al 2009

51

Implications

LGM demonstrates atrophy, more evident in advanced stages of pathology

<u>UGM, like TFL</u> does NOT readily atrophy in the presence of degenerative hip pathology

UGM & LGM should be considered functionally separate muscles & may require differing approaches in targeted management of muscle dysfunction.

UGM is more functionally similar to TFL. Excessive bulk and activity in the upper portion of the gluteus maximus may not be healthy for the underlying joint. Assess & target UGM & LGM as 2 separate muscles.

52

Glut Max Fibre Type ∆ & Hip OA

Selective loss of fast twitch fibres in gluteus maximus has been demonstrated in patients with hip OA
(Sirca & Susec Micheli, 1980)

Implications:

Poorer capacity for strength development & shock absorption - increased joint forces

Potential to shift towards more tonic function

Important to address fast twitch fibre function & to ensure avoidance of excessive tonic activation strategies for GM in functional retraining & therapeutic exercise

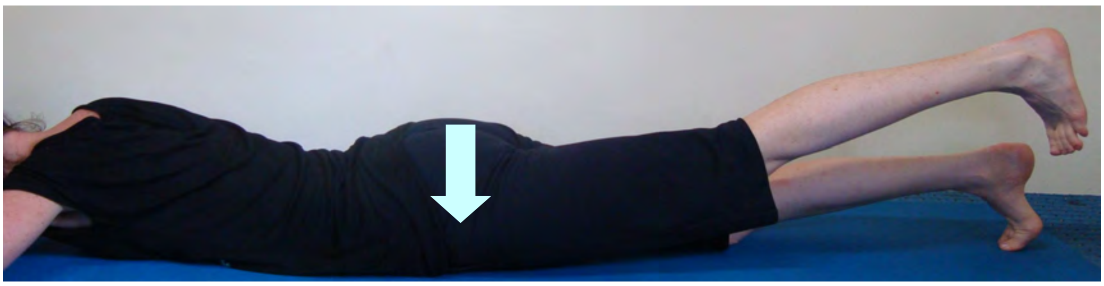
53

Hip extensor exercise & joint forces

Lewis et al 2009

Measured joint forces in a simulated biomechanical modelling study. Looked at ranges between 10° flexion and 20° extension in a prone hip extension model.

Highest hip joint forces (*ant), occur in hip extension esp if gluts are weak.



54

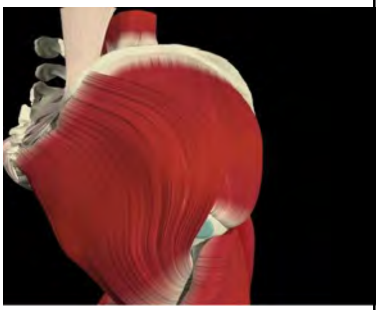
Topics for Discussion

Normal function

Gluteus maximus & joint pathology

Gluteus maximus & unloading

Implications for therapeutic exercise



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Unloading: Insights for Aetiology?

Muscle deficits in OA – chicken or the egg?

Muscle deficits have been linked to the development and progression of OA at the knee (Slemender et al 1998, Hurley 1999) and hip (Hootman et al 2004)

Lack of appropriate loading of the musculoskeletal system is thought to be one of the factors leading to the development of muscle deficits (Richardson 2004)

Microgravity research provides the opportunity to observe patterns of muscle change during unloading in healthy subjects

Unloading studies have shown preferential atrophy of antigravity muscles, slow twitch muscle fibres, and intrinsic stabilisers at the Lx & knee (Fitts et al 2000, Hides et al 2007, Musacchia 1992)

56

Berlin Bed Rest Study

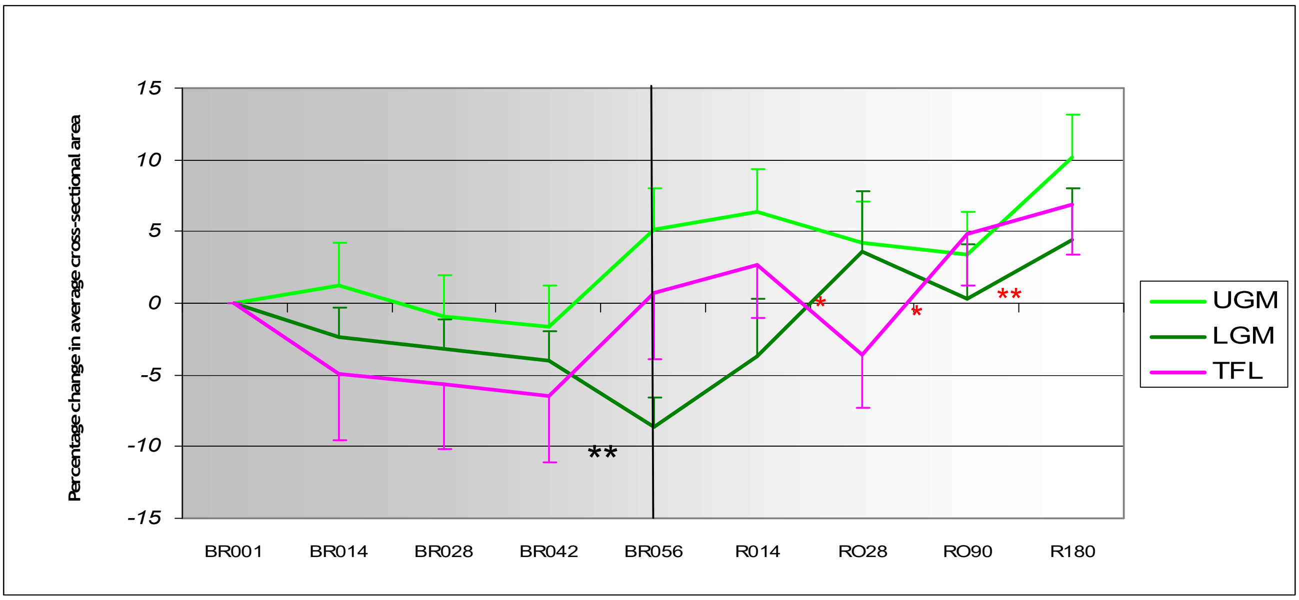
The University of Queensland Australia

- Young healthy males restricted to bed for 8 weeks
- MRI's were taken at baseline, every 2 weeks during bed rest, & 5 times during the ambulant recovery period – 180 days
- Countermeasure group performed exercises in bed on a bed mounted whole body vibration platform
  - squats
  - jumps
  - heel raises
  - toe raises

Straps provided 1.8 x BW axial compression onto the plate

57

GMax/TFL during BR & recovery



58

Implications

LGM & UGM demonstrated differing patterns of response to unloading

While LGM was significantly affected by unloading (7.3%± 7.2% atrophy by 8 weeks), the UGM was not, like the other superficial hip abductor TFL

This reflects the patterns seen in the presence of degenerative joint pathology and implies that it is possible that loss of hip extensor bulk may precede and contribute to the development of hip OA.

59

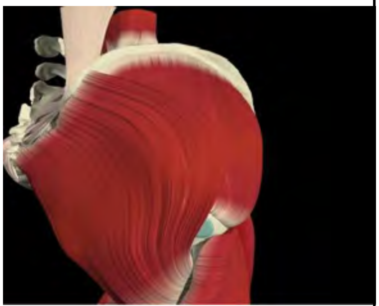
Topics for Discussion

Normal function

Gluteus maximus & joint pathology

Gluteus maximus & unloading

Implications for therapeutic exercise



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Implication for Therapeutic Exercise

Considering:

1. LGM is an antigravity extensor, negatively impacted upon by unloading &
2. Joint forces (*Ant) are increased in hip extension, particularly if gluteals are weak (Lewis et al 2009), leading these authors to state that hip extension past neutral is not recommended for patients with hip OA to limit compressive loading across joint

Which exercises will be most functionally consistent for this muscle, and safest for the underlying joint?

61

Therapeutic Exercise for Lower Glut Max

62

Use gravity to your advantage

63

Use gravity to your advantage

TWS Slider, PhysioTec

64

GMax in gait & posture

Considering:

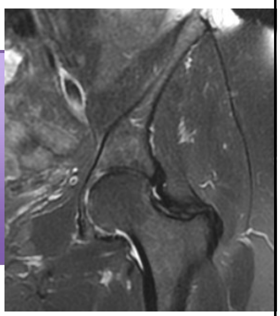
1. GM is not tonically active during quiet standing or gait &
2. GM experiences a selective loss of fast twitch fibres in hip OA, therefore a shift towards a slower phenotype

Cues given for posture & gait should be consistent with the natural function of this muscle

- GM should not be held tight during quiet bilateral standing
- GM should be phasically active during gait- to prepare for and absorb ground reaction forces at heel strike, and additionally in running to rapidly extend the hip to bring the foot back to the ground.

65

Lesson 5:
The hip abductor synergy
Function & Dysfunction



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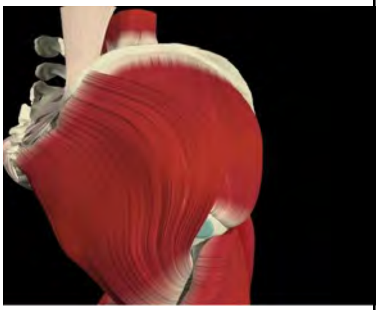
66

Topics for Discussion

- Normal function
- The hip abductors & joint pathology
- The hip abductors & unloading
- Implications for therapeutic exercise



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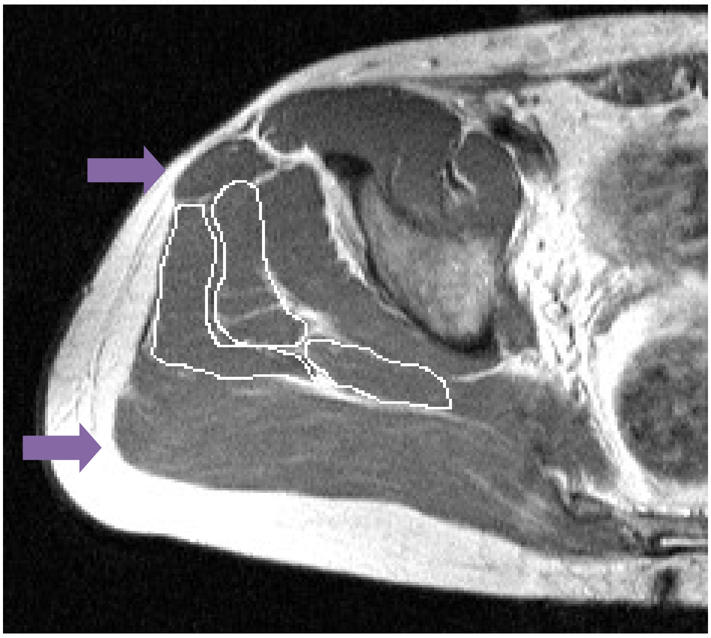
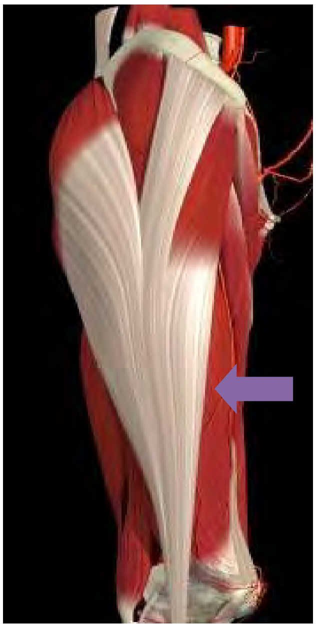
The hip abductor synergy

Superficial System – Upper Gluteus Maximus, TFL, VL





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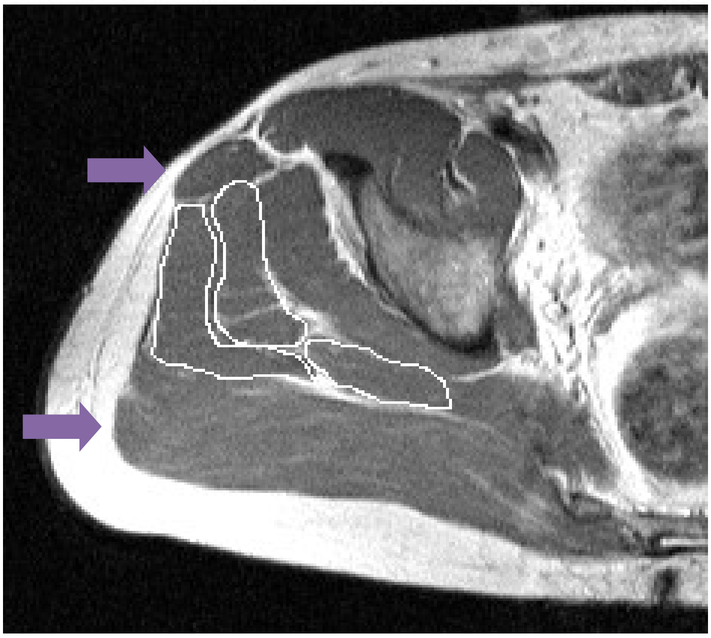
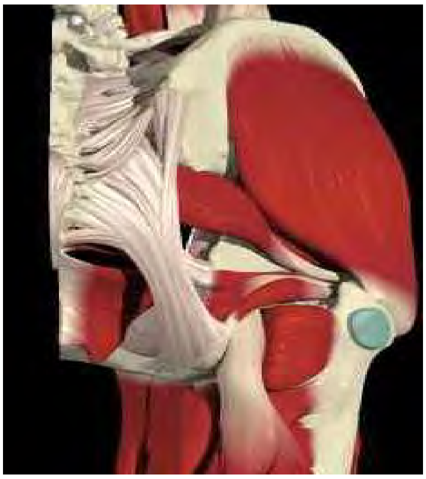
The hip abductor synergy

Intermediate System – Gluteus Medius, Piriformis





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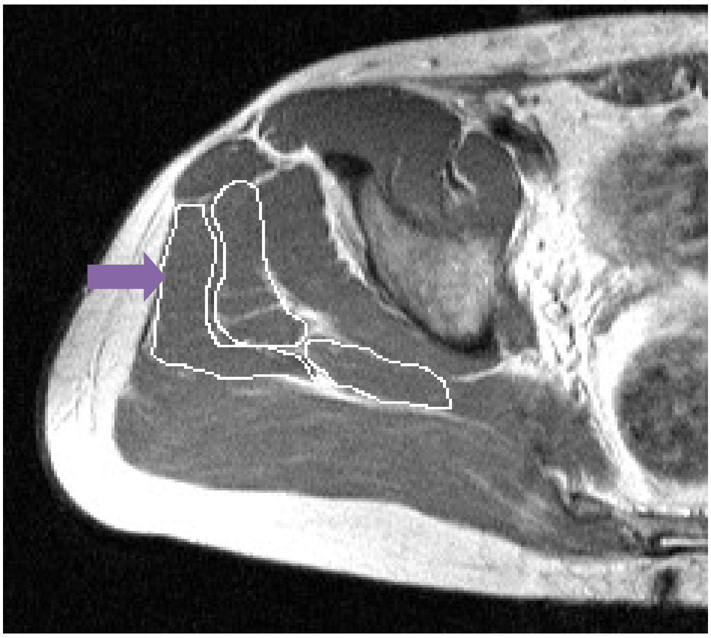
The hip abductor synergy

Deep System – Gluteus Minimus



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Superficial System

TFL & UGM with ITB

Deltoid of the hip

Gluteus Maximus

Upper Glut Max:

1° Abd function (+ER)

Lower Glut Max:

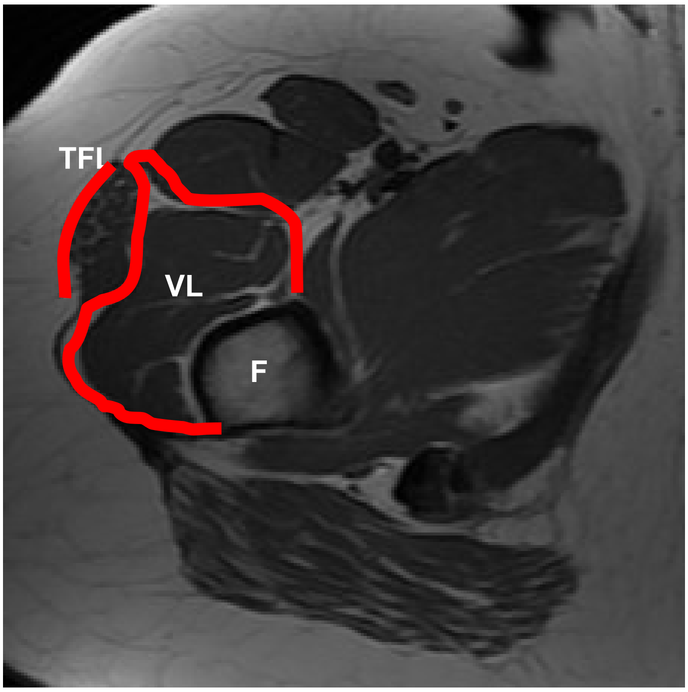
1 ° Ext Function (+ER)

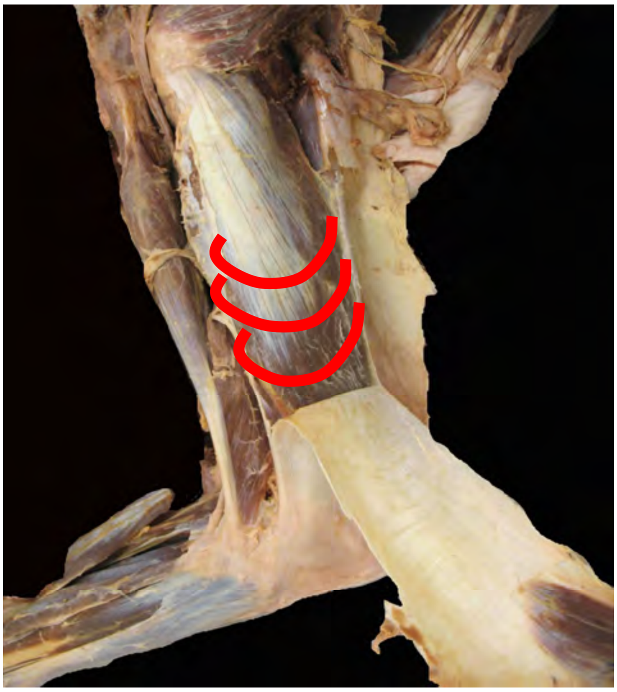
Vastus Lateralis

Pictures © Primal Pictures Ltd

71

Effects of VL





72

VL & poor hip abductor function

Both altered vasti activity & poor abductor strength have been demonstrated in PFJP

(Cowan et al 2002, Ireland et al 2003, Mascal et al 2003)

Clinically we often see increased VL bulk & activity in those with poor hip abductor function (even in absence of knee pain)

73

Gluteus Medius & Piriformis

Changing Function of Gluteus Medius & Piriformis Through Range		
	At 0° Hip Flexion	At 90° Hip Flexion
Anterior Gluteus Medius	Internal rotation	Internal rotation
Middle Gluteus Medius	Abduction	Internal rotation
Posterior Gluteus Medius	External rotation/ abduction	Internal rotation/ abduction
Piriformis	External rotation/ abduction	Internal rotation/ abduction

Delp et al 1999, Dostal, Soderberg & Andrews 1986

74

Gluteus Medius

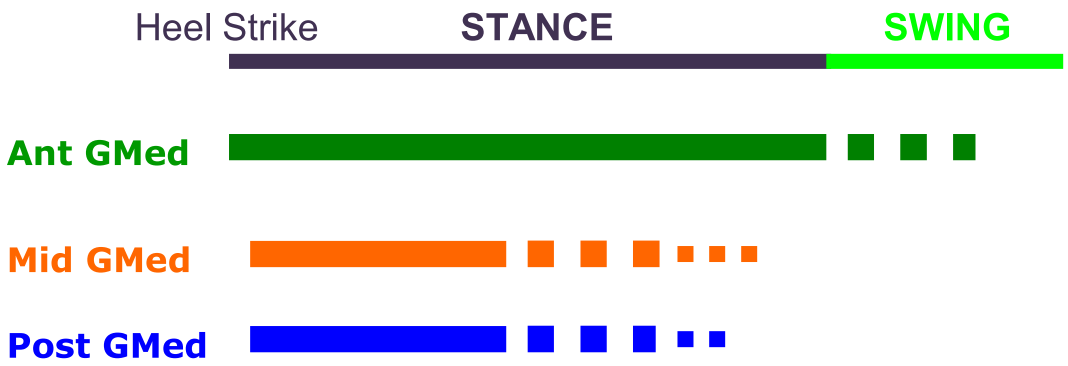
Anterior & Posterior portions sit deep to the middle or 'lateral superficial' portion – implications for surface EMG

Deeper parts may be more involved in joint protection, superficial parts more in torque production

75

Glut Med EMG in gait

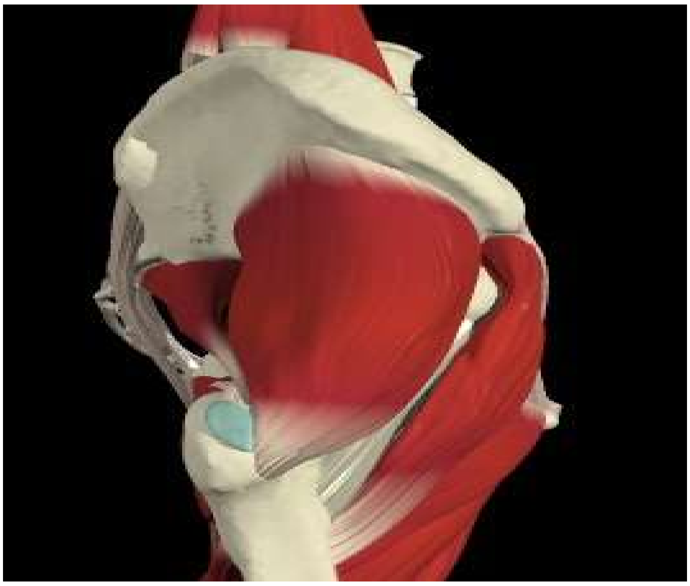
Adapted from Soderberg & Dostal 1978

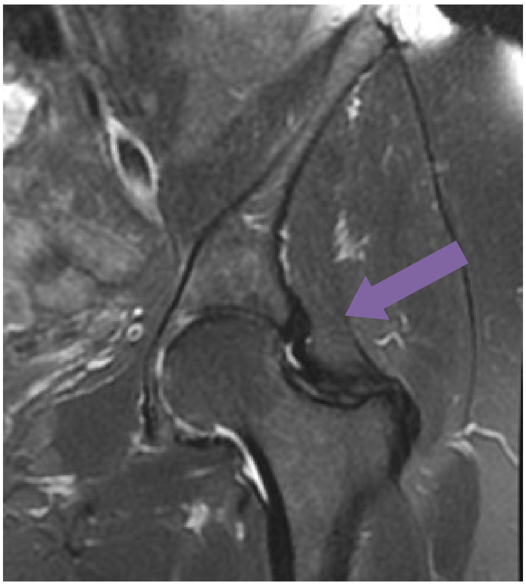


The 3 portions of the gluteus medius have been shown to be distinct functional entities with separate nerve supply (Gottschalk et al 1989)

76

Gluteus Minimus





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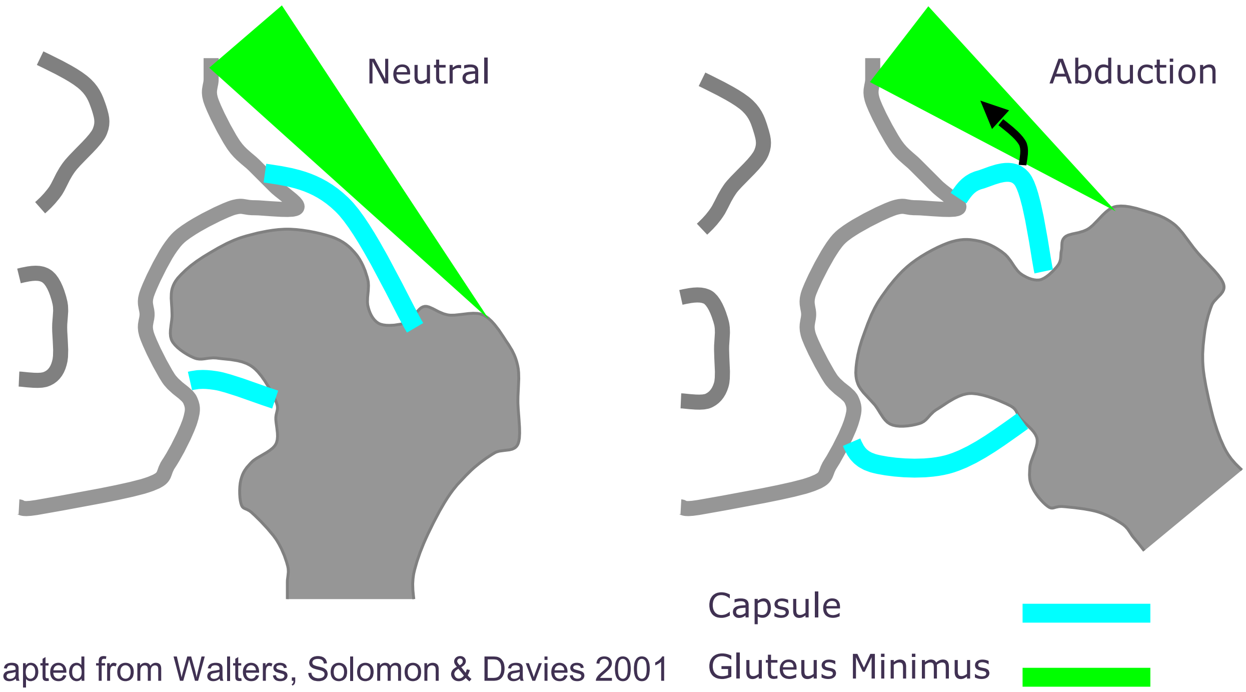
Strong attachment to the superior joint capsule (Walters et al 2001)

77

Gluteus Minimus & the Capsule



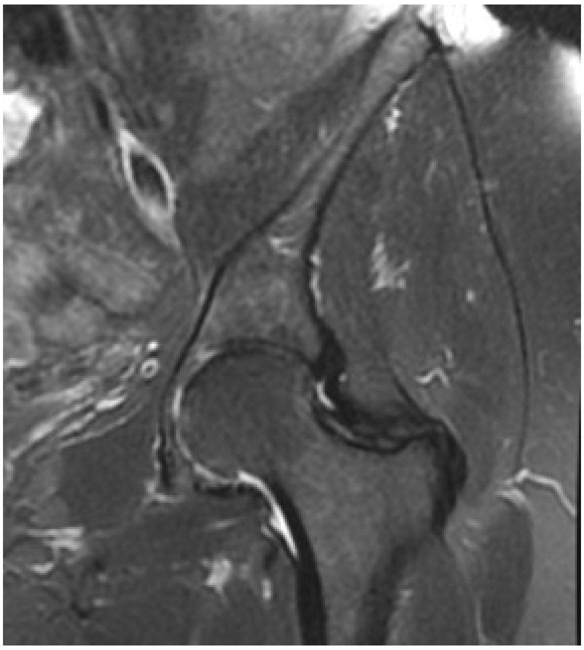
Adapted from Walters, Solomon & Davies 2001

78

Gluteus Minimus

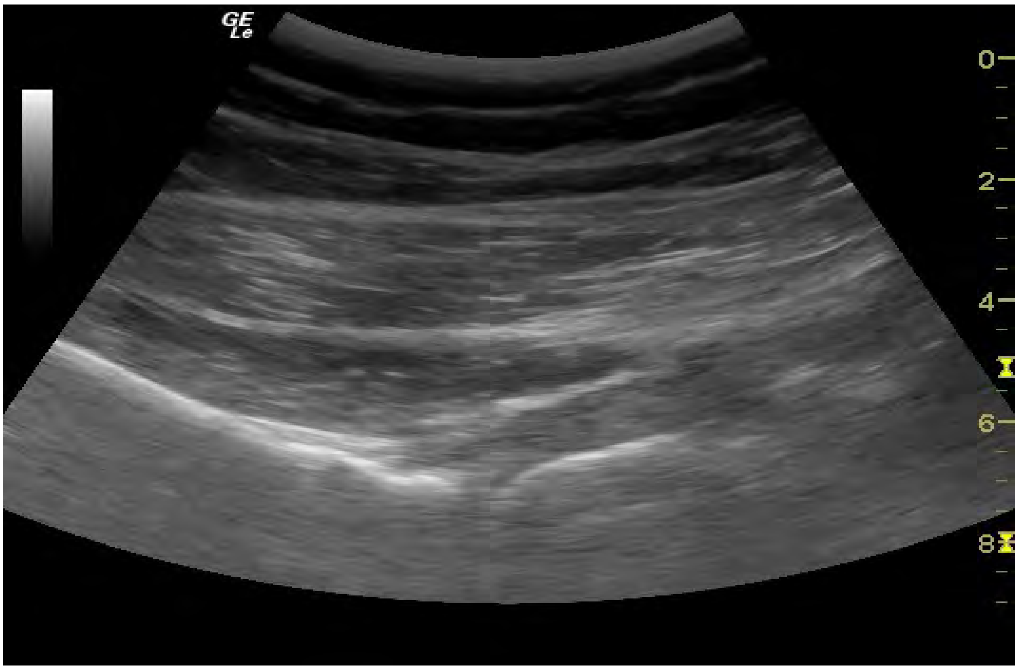
Glut Min resists superolateral & anterior migration of femoral head (Beck et al 2000)

Glut Min active in all directions except add (open chain) (Wilson et al 1976)



79

Gluteus Minimus Dynamic Function: Normal



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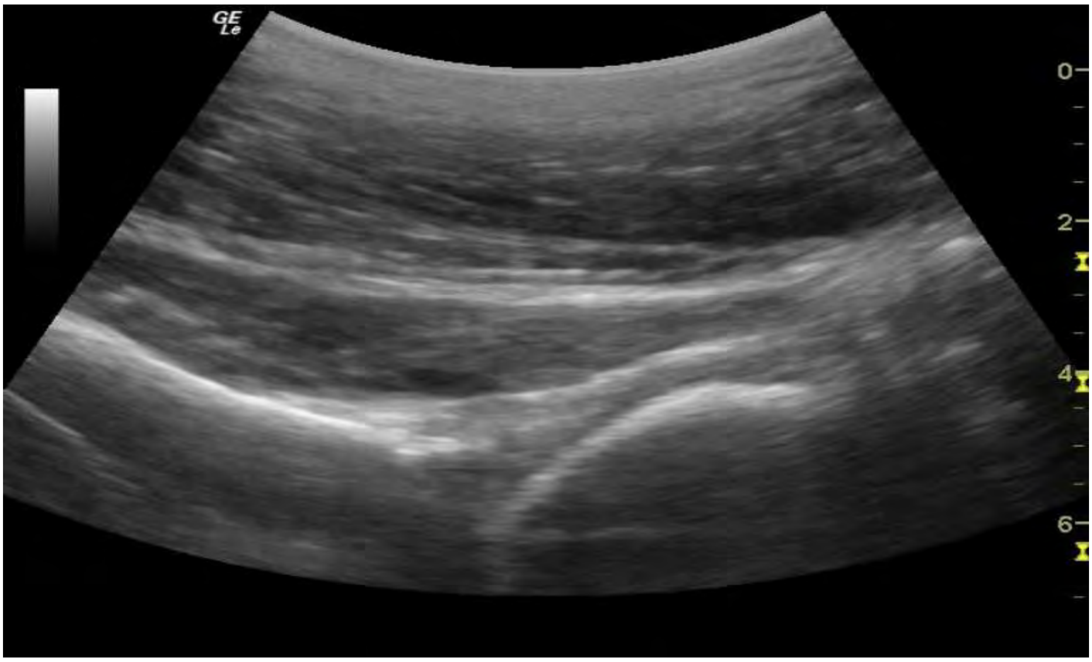
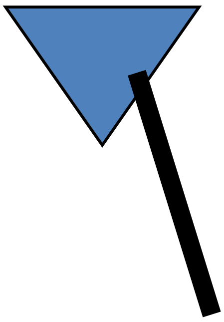
Gluteus Minimus Dynamic Function: Young painful hip

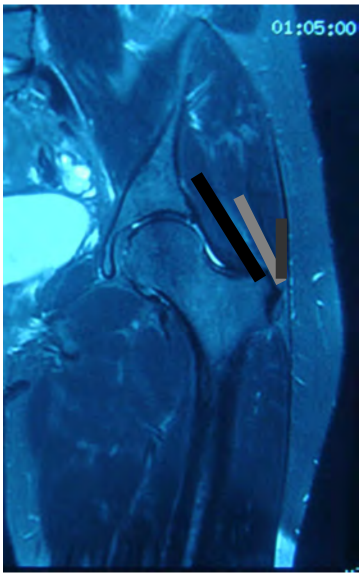


81

Normal abductor function

Kumagai et al 1997





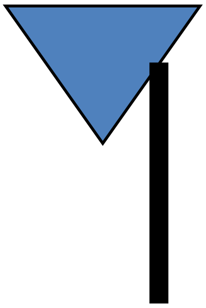
GMin active in all positions of hip abd/add

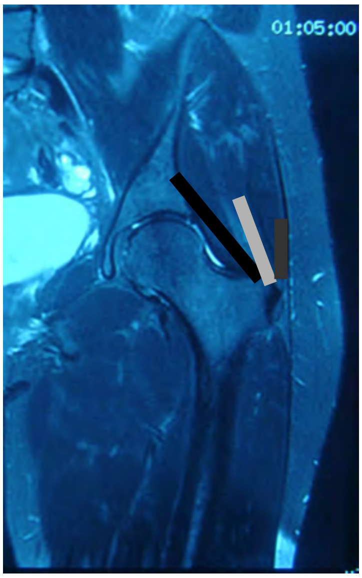
GMed, esp sup portions least active in posn of hip abd

82

Normal abductor function

Kumagai et al 1997



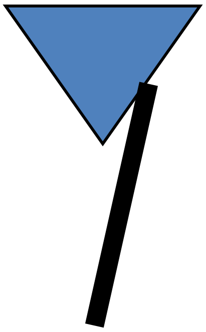


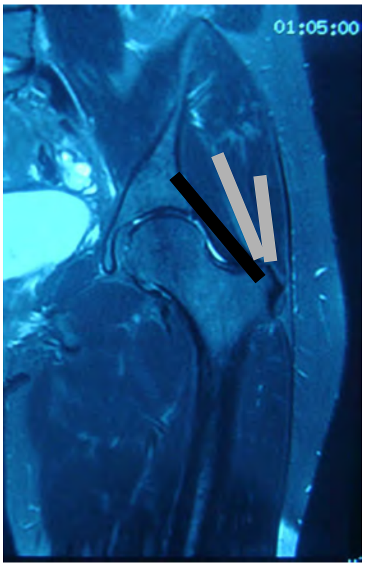
Deep GMed more active in hip neutral
Superficial GMed still relatively less active

83

Normal abductor function

Kumagai et al 1997





Superficial GMed now much more active

Most torque produced from position of Add

Greater mechanical advantage for TFL/UGM/VL also

84

Clinical Relevance

Function in hip adduction appears to be associated with relatively greater activity in the superficial abductors – Sup GMed, TFL, UGM

Control of functional hip adduction may be critical to optimal balance in the abductor synergy

85

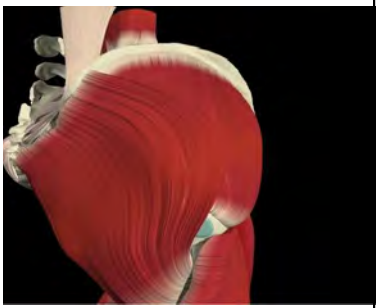
Topics for Discussion

Normal function

The hip abductors & joint pathology

The hip abductors & unloading

Implications for therapeutic exercise



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86

Dr. Alison Grimaldi
PHYSIOTHERAPIST, RESEARCHER & EDUCATOR

Hip Abductors & OA: Strength

Source	Abductor Strength Deficit
Arokoski et al 2002 J Rheum 29:2185-2195	31% less than normals Mixed grades of pathology
Rasch et al 2007 Acta Orthopaedica 78:505-510	14% less than affected side in pts with unilateral OA Pre THR
Sims et al 2002 Ann Rheum Dis 61:687-692	No difference between sides or compared with normals Earlier OA
Teshima 1994 Acta Med Nagasakiensia 39(3): 21-30	No difference in strength between controls and pts with early & advanced OA. Weaker only in end stage OA

87

Why the discrepancy?

Stage of OA?

Method

Strength testing provides an indication of gross function of the *whole* abductor synergy

Normal strength ≠ Normal function

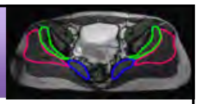
88

Hip Abductors & OA: EMG

Source	TFL Activity	GMed Activity
Long et al 1993 Clin Orthop Rel Res 288: 73-77	Increased	Decreased
Sims et al 2002 Ann Rheum Dis 61:687-692	Trend to increase	**Increased** cw normals

89

Hip Abductors & OA: Size



Muscle	Mild OA	Advanced OA
UGM	No change	No change (aff side)
TFL	No change	No change
Piriformis	No change	Atrophy
Glut Med	**Hypertrophy 16%>N**	Atrophy
Glut Min	No change	Atrophy (Trend)

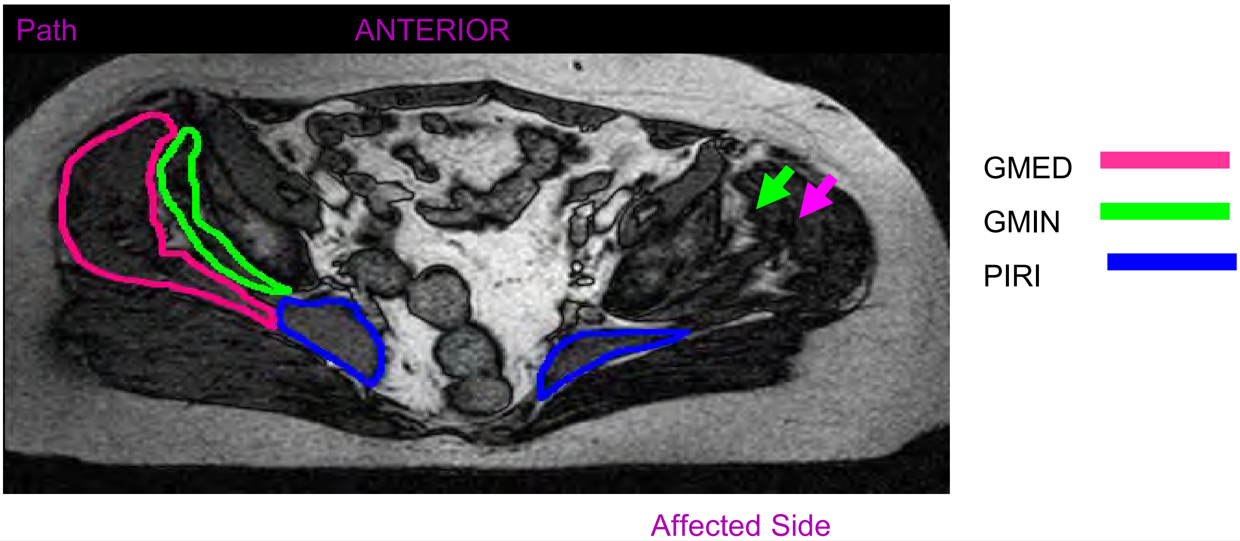
Grimaldi et al: Manual Therapy: doi: 101016/imath200907004

90

Advanced unilateral hip OA

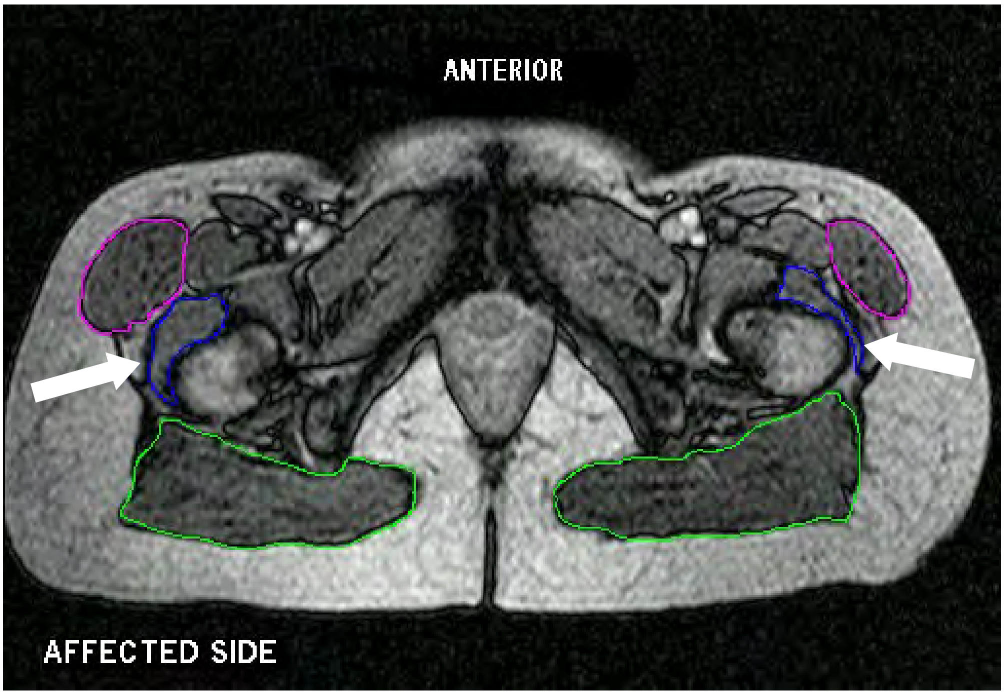
Deep abductor muscles smaller on the affected side

GMED: 12% ($p<0.01$); GMIN 8.2% (NS); PIRI 14.4% ($p<0.05$)



91

And what's happening with that VL?!



92

Hip Abductors & OA: Fibre Type △

Progressive loss of fast twitch fibres in TFL, GM and GMED (superficial) in patients with hip OA
(Eimre et al., 2006, Ŝirca & Suŝec-Micheli, 1980)

Implications:

Poor capacity for strength development & shock absorption - increased joint forces

Early THR prior to irreversible changes??

Early targeted exercise

93

Hip Abductors & OA: Function

Early OA

Increased WB hip adduction

Watelain 2001

Advanced OA

Trunk LF, reduced hip add

Offloading

strategy

(Krebs et al 1998)

94

Putting it all together

Stage OA	Function	EMG	Size	Fibre type
Early 	↑ hip add ↑ Sup GMed	↑ GMed Superficial ↑ TFL	GMed Hypertrophy	?
Advanced 	↑ trunk LF Offload GMed	↓ GMed TFL tonic	GMed & min atrophy TFL/UGM maintain	UGM,TFL, Sup GMed slow & stiff ? Deep become phasic

95

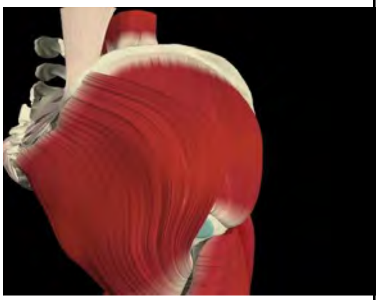
Topics for Discussion

Normal function

The hip abductors & joint pathology

The hip abductors & unloading

Implications for therapeutic exercise



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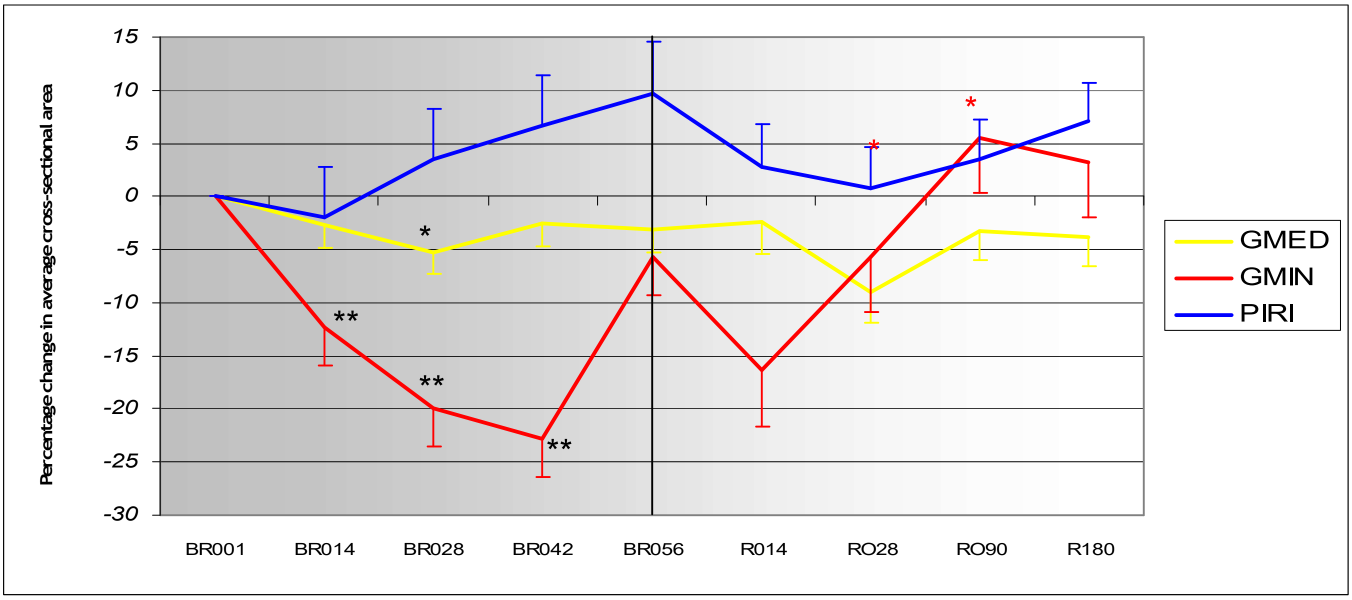
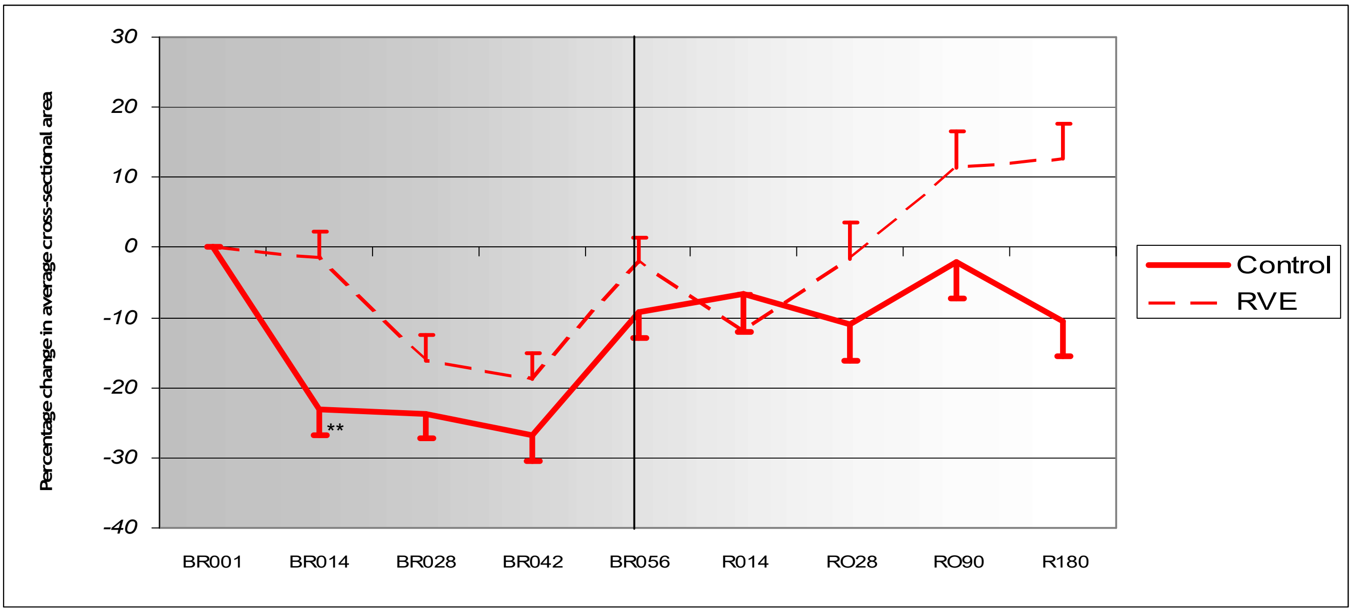
Hip abductors & unloading: BBR

UGM & TFL **NO** atrophy; Deeper abductors: GMin ++atrophy



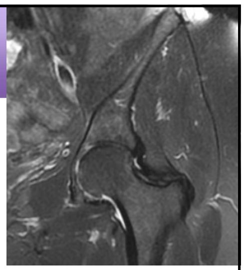
97

Response of Gluteus Minimus



98

Implications for muscle function



GMIN is potently affected by unloading, greater than any other human muscle studied to this point

Other joint stabilisers such as MT (10% loss at BR14: Hides et al 2007) & VM are also preferentially affected by unloading, **lending support to a stability role for GMIN**

GMED showed a more variable response likely related to independent responses of each portion

PIRI is not affected by unloading, unlikely a 'local stabiliser'

99

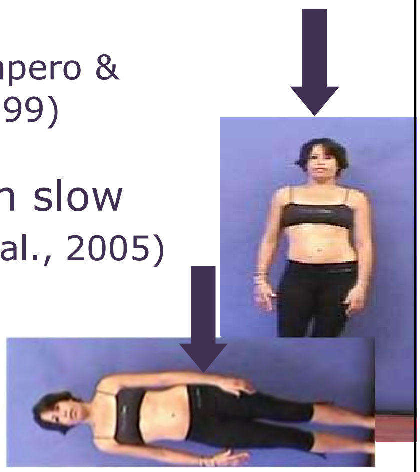
GMin 'recovery' in last 2 weeks BR??

May reflect a change in muscle function, and a shift towards a fast twitch bias

Microgravity literature has shown

- preferential atrophy of ST fibres (DiPrampero & Narici, 2003, Fitts et al., 2000, Widrick et al., 1999)
- EMG shift from tonic to phasic activity in slow type ms (de-Donker et al., 2005; Kawano et al., 2005)

During bed rest gravity is not eliminated but shifted by 90°



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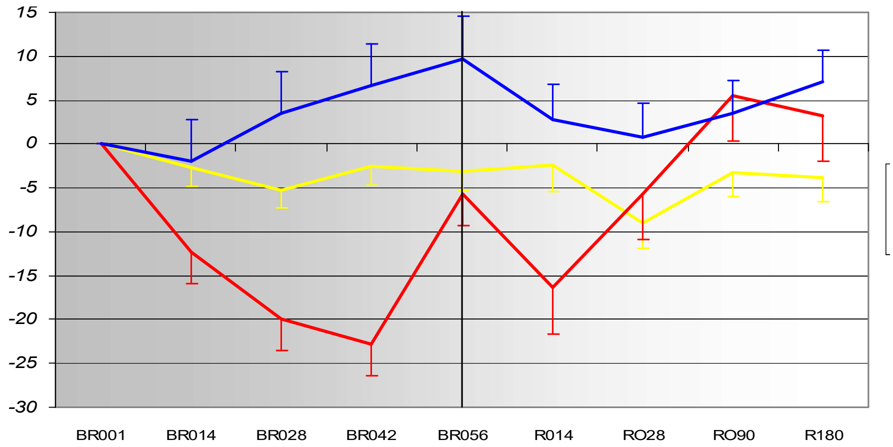
GMin 'recovery' in last 2 weeks BR??

Function in lying may ⬆ FT fibre stimulus/ ⬇ ST stim

6 weeks is the accepted time frame for muscle fibre hypertrophy

Theory supported by recovery phase reversal



101

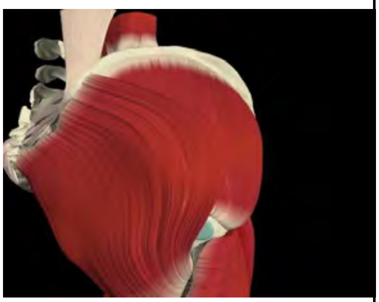
Topics for Discussion

Normal function

The hip abductors & joint pathology

The hip abductors & unloading

Implications for therapeutic exercise



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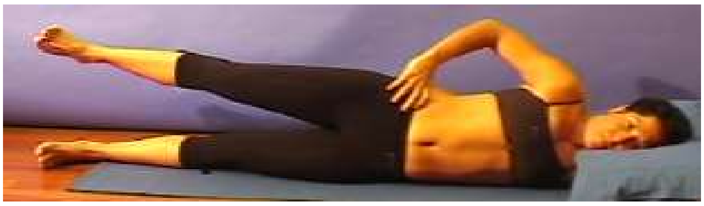
102

Implications for exercise: BBR

Specificity not only of *which* muscles are recruited but *how* they are recruited may be integral to the success or failure of prevention & management programmes for hip OA

Open chain abductor exercise esp in horizontal postures may preferentially recruit superficial muscle systems.

103

Implications for Exercise: OA

Stage of pathology & associated functional patterns will influence approach

Gross strengthening may not be the best approach for early joint disorders

Exercise approaches should target specific deficits in both deep and superficial musculature

104

Implications for Exercise: OA

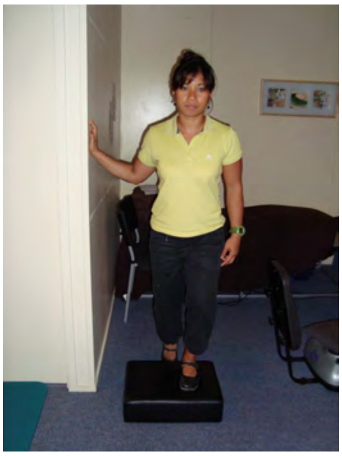
GMin – Early activation, tonic holding ability, ?effect on capsule – RTUS allows visualisation of GMin function

Superficial musculature – requires strength & speed training & training in eccentric energy absorption. Perturbation training may provide an opportunity to influence the feed-forward system (Chmielewski et al 2005) and prevention over-recruitment & tonic activity of the superficial musculature.

105

Implications for Exercise

Minimising functional adduction is likely a key factor in optimising balance in contribution from members of the abductor synergy



106

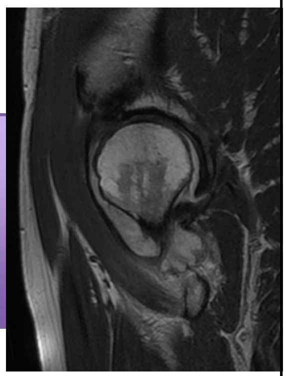
Implications for Exercise

Using inner range abduction should help to re-direct preferential activation towards deeper abductors. Weight-bearing should further assist in activation of the deeper members. Sliding platforms with spring resistance can be very useful tools.

TWS Slider

107

Lesson 6:
The hip flexor synergy
Function & Dysfunction



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108

Topics for Discussion

- Normal function
- The hip flexors & joint pathology
- The hip flexors & unloading
- Implications for therapeutic exercise

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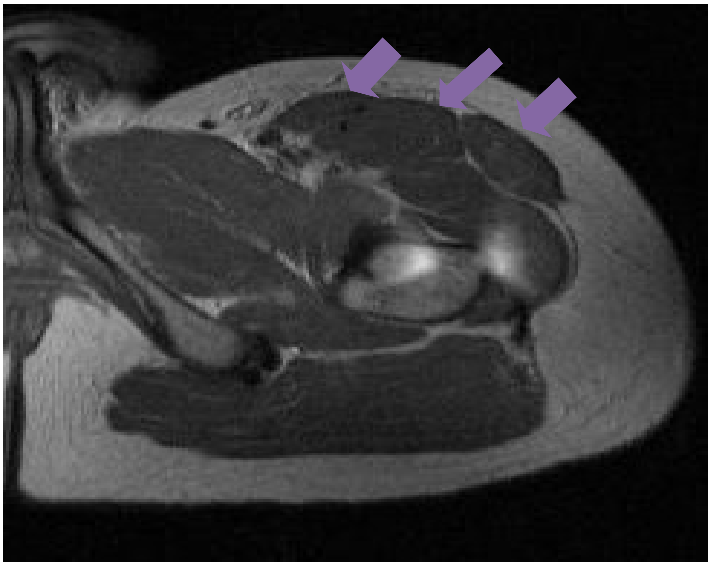
109

The hip flexor synergy

Superficial System – Sart, RF, TFL, ADL, Pectineus, 2° - ADB, Gracilis



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The hip flexor synergy

Intermediate System – Iliopsoas

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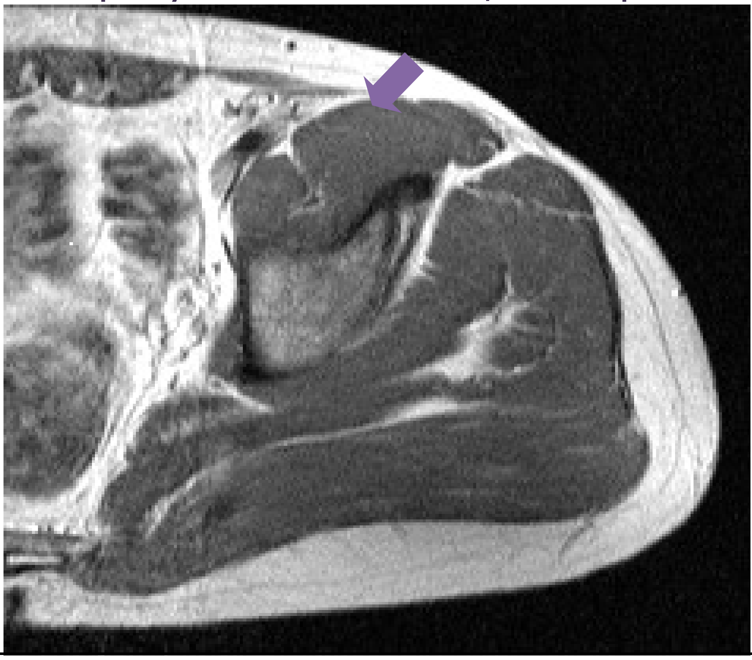
The hip flexor synergy

Deep System – Iliacus, iliocapsularis



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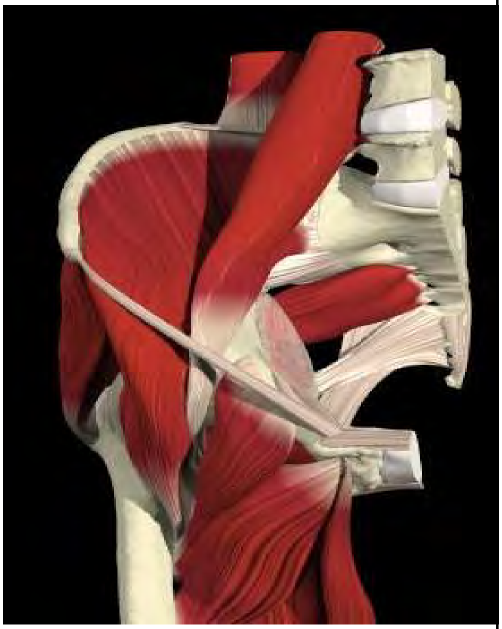
Iliopsoas

Psoas is thought to have a role in:

- trunk on femur control
  (Andersson et al 1997,
  Thorstensson et al 1984)
- & possibly in spinal stability
  (Penning 2000)

Psoas becomes tendinous at the pelvic brim as it passes under the inguinal ligament.



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Iliacus

Medial iliacus fibres end up deepest at the front of the hip. Iliacus tendon develops within these fibres, lateral to the psoas tendon. These tendons join a few cms above lesser trochanter.

The most lateral fibres sit superficially at the anterior hip, and insert directly onto the anterior femur, just at and below the level of the lesser trochanter.

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Iliopsoas

- Iliopsoas fibre typing in young human males showed an average 50:50 type 1: type 2. (Johnson et al 1973)
- Iliacus fibre typing in animal histology studies showed deepest fibres at front of hip are short & up to 73% slow twitch fibres (Roy et al 1997)
- Possibly more torque production from lateral superficial fibres and stability from deeper/more medial fibres

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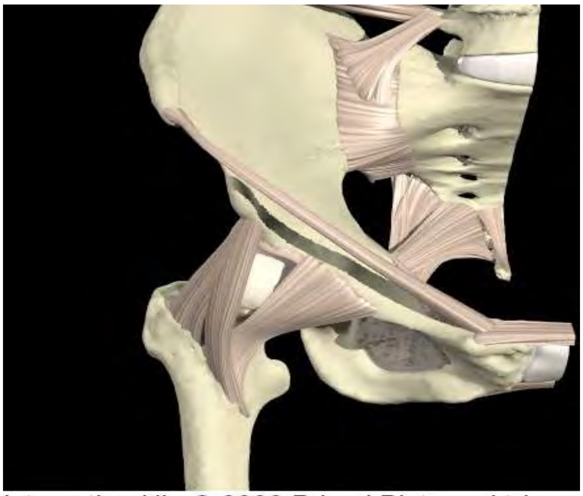
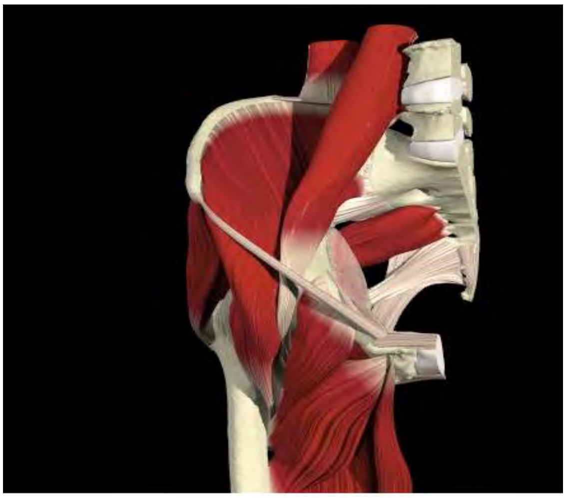
Iliacus





Iliacus crosses the front of the hip joint, supporting an area deficient in ligamentous support

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116

Sagittal View - Iliopsoas

Anterior

Posterior

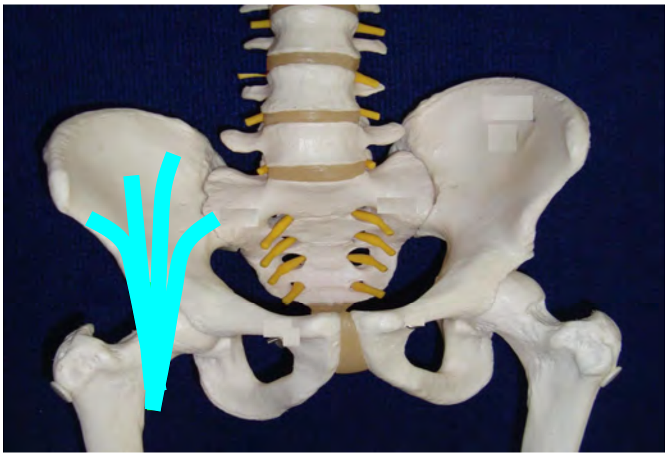
117

Iliocapsularis

Iliocapsularis originates from just below AIIS, below origin of RF, & from the anterior joint capsule

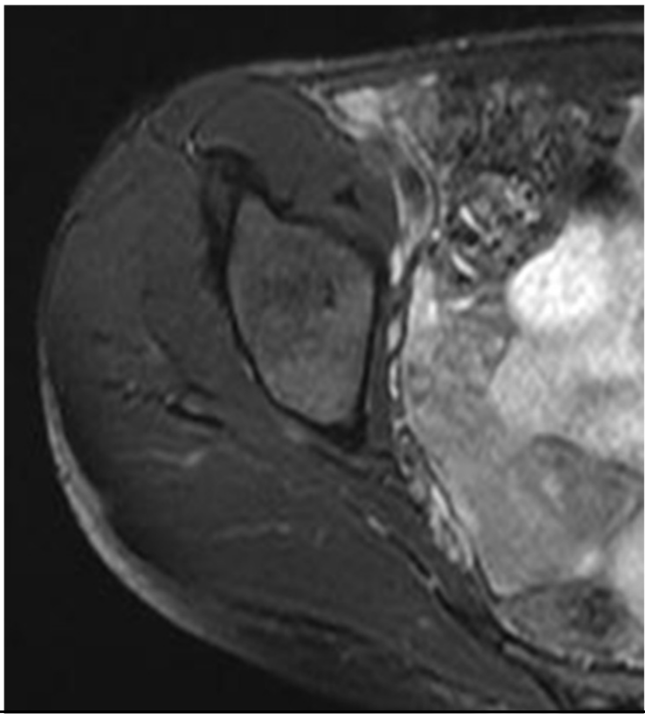
Inserts just below lesser trochanter

Ward et al 2000



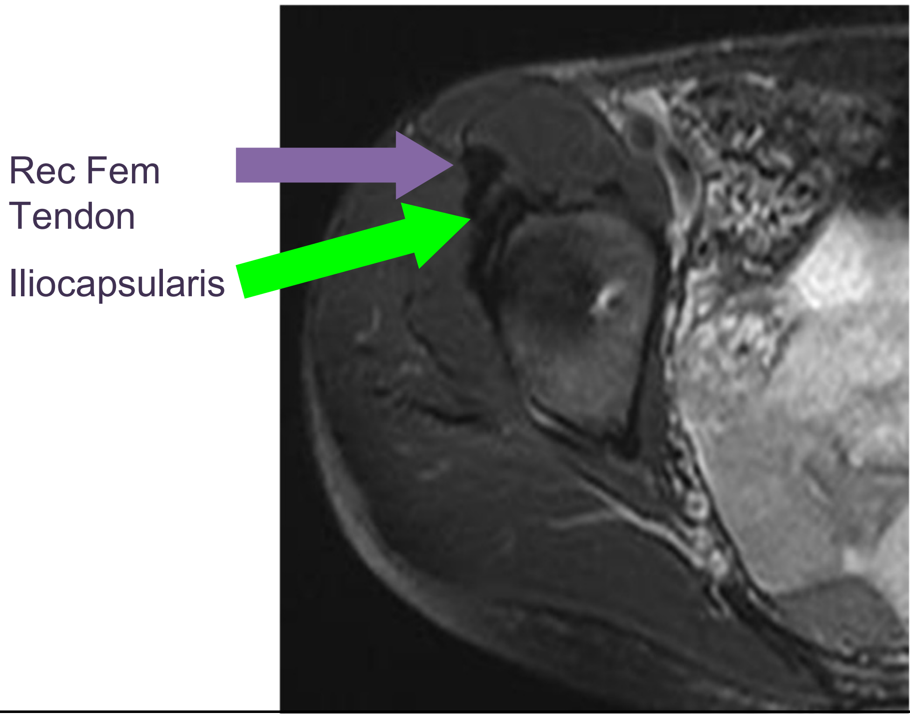
118

Iliocapsularis



119

Iliocapsularis

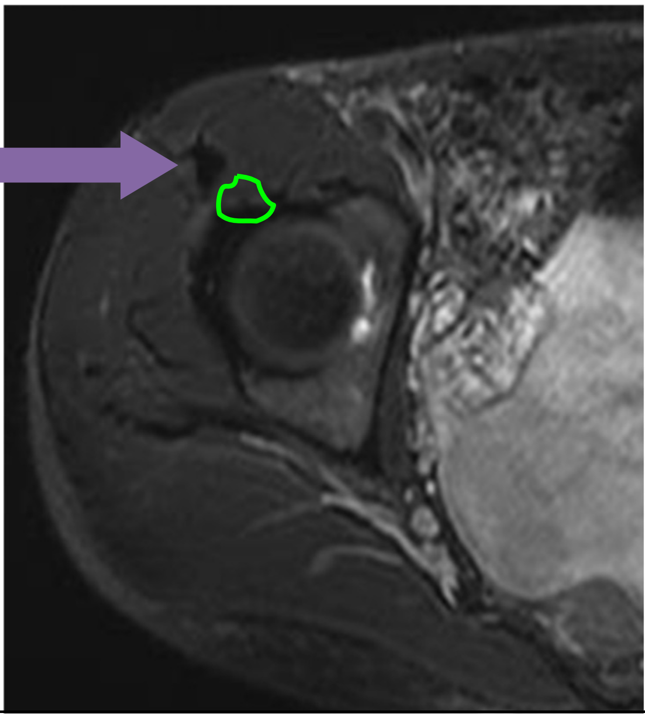


120

Iliocapsularis

Rec Fem Tendon

Iliocapsularis



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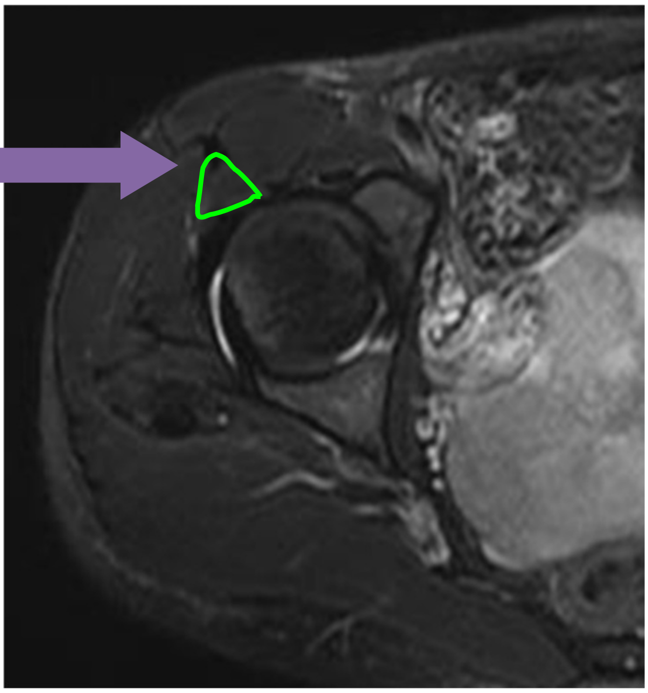
Iliocapsularis

Rec Fem Tendon

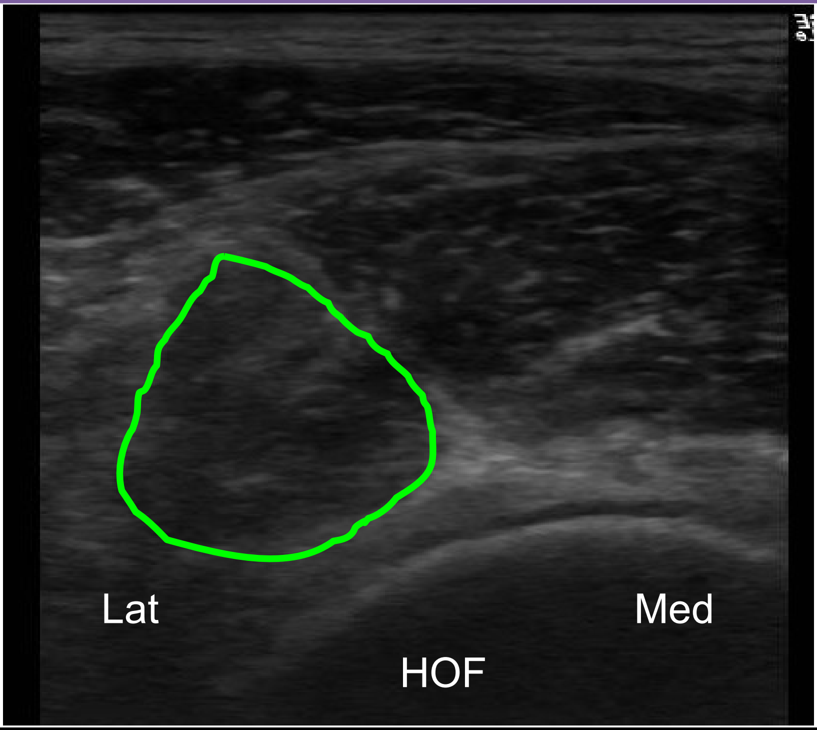
Iliocapsularis



122

Iliocapsularis on ultrasound

Transverse view anterior hip

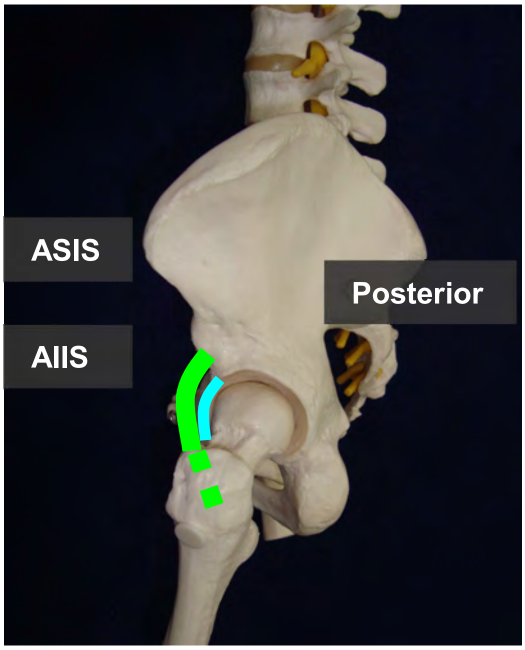


123

Iliocapsularis

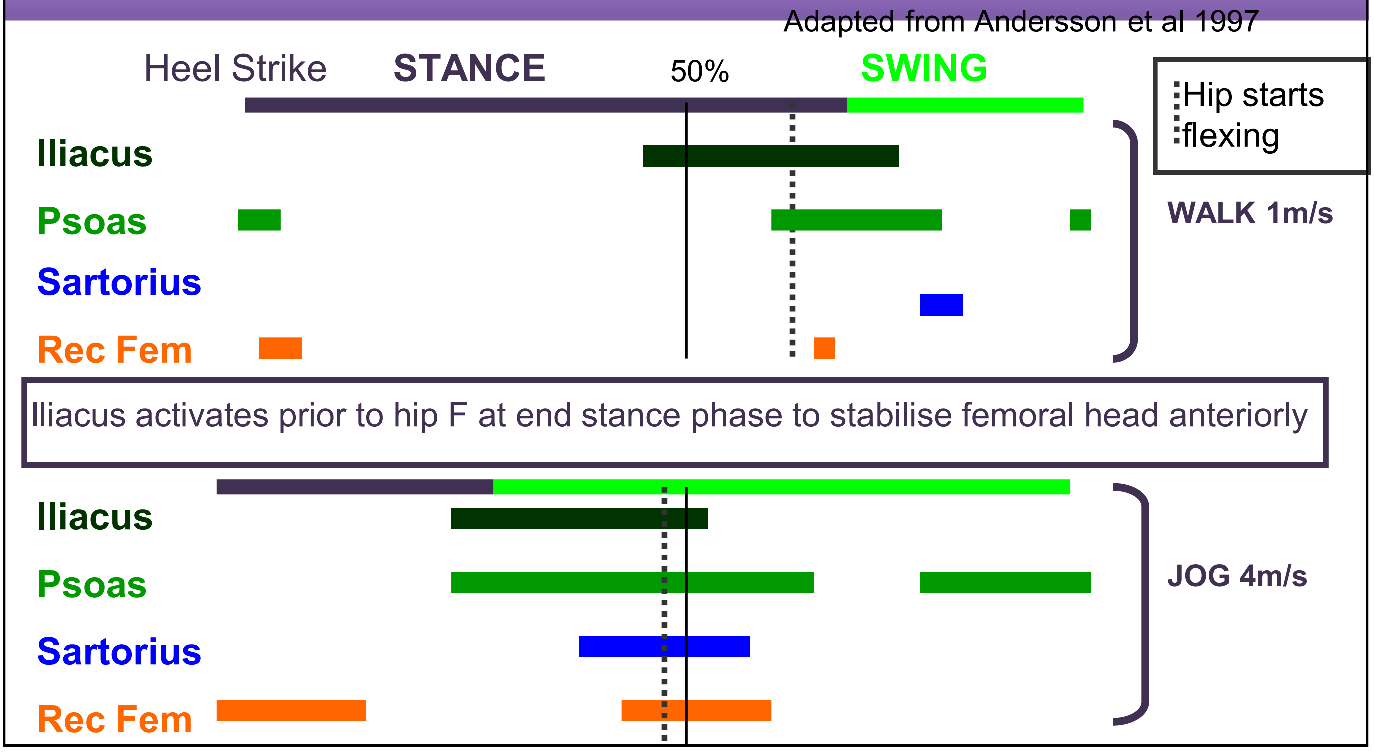
- Believed to function as a tightener of the hip joint capsule
- In acetabular dysplasia this muscle has been noted to hypertrophy

  Ward et al 2000



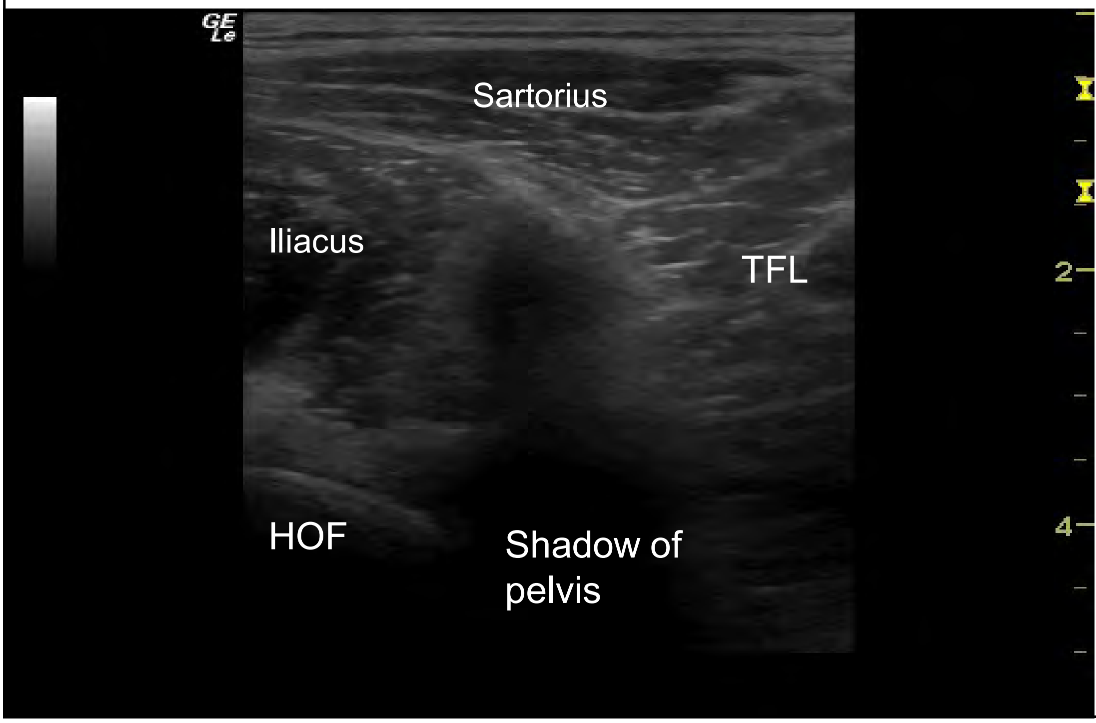
124

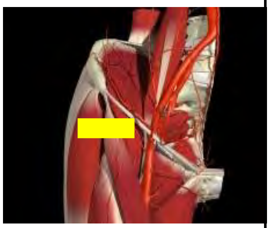
Hip Flexor EMG in gait



125

Hip Flexors Dynamic





Picture above © Primal Pictures Ltd

Transverse view anterolateral hip

126

Hip flexors & joint loading

Lewis, Sahrmann, Moran 2009

Modelling study of SLR: 10° hip extension to 30° flexion

Highest joint forces in hip ext with weak iliacus & psoas

Reduction of IP force increased joint force by 140units

Reduction of RF, Sart, & TFL only increased by 16.4 units

Weakened IP
→ increased TFL
→ increased abduction force
→ increased AL
→ increased overall jt force

127

Topics for Discussion

- Normal function
- The hip flexors & joint pathology
- The hip flexors & unloading
- Implications for therapeutic exercise

Picture © Primal Pictures Ltd

128

Hip flexors & joint pathology

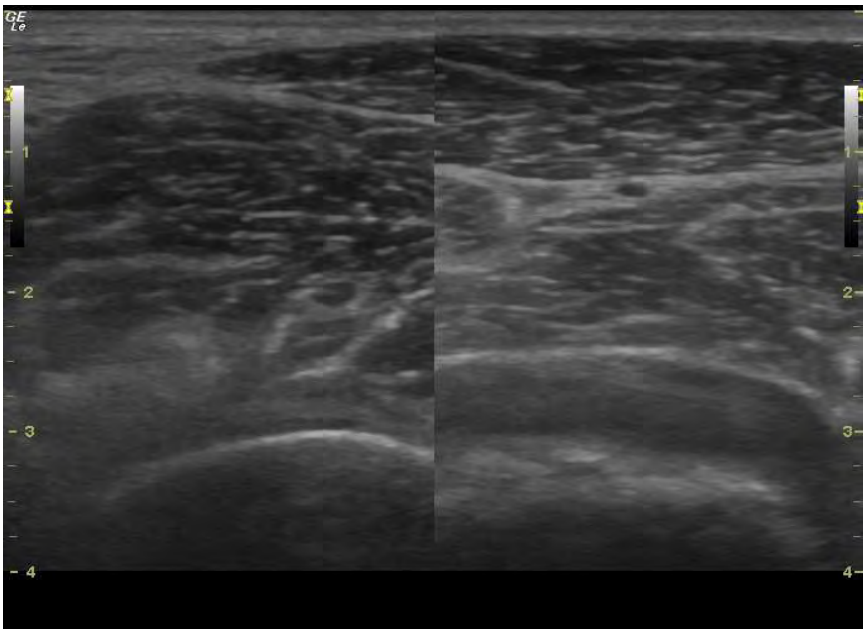
For patients with hip OA, pre THR

- Hip flexor strength most significant torque reduction for mm's around hip in subs day before THR – mean 27%<N
- Hip flexor size reduced by mean 19% compared with good hip – only measured psoas

Rasch et al 2007

129

Hip Flexors in hip OA



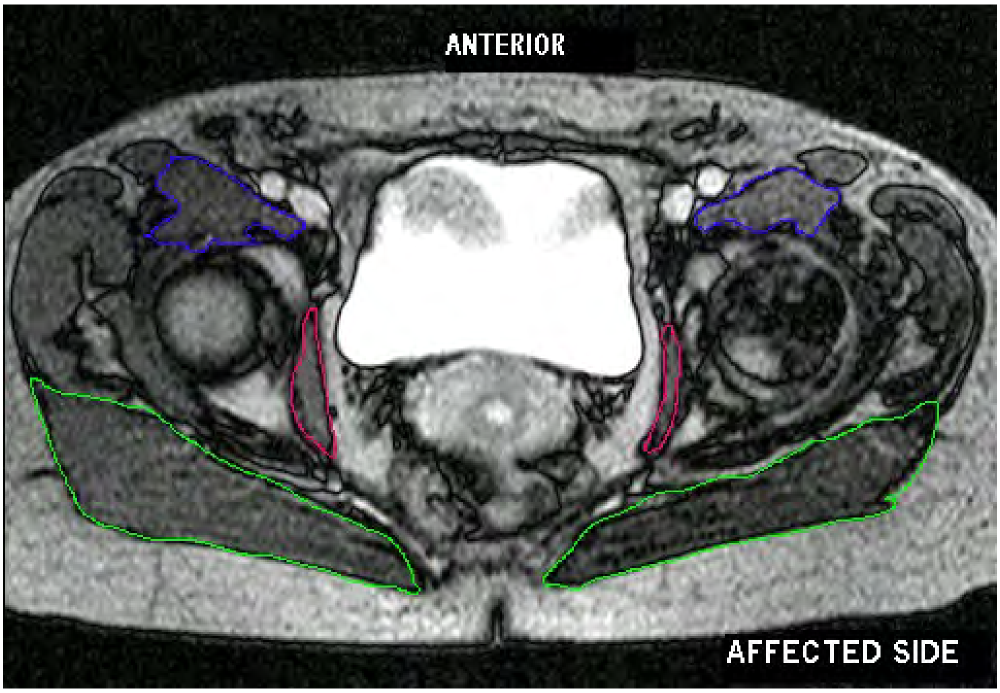
Iliopsoas: Unaffected hip vs OA hip

Picture © Primal Pictures Ltd

Transverse view ant hip

130

Iliacus in subjects with hip joint pathology



IL

OI

GM

131

Topics for Discussion

Normal function

The hip flexors & joint pathology

The hip flexors & unloading

Implications for therapeutic exercise

Picture © Primal Pictures Ltd

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Hip flexors & unloading: BBR

Mendis, Hides, Wilson, Grimaldi et al 2009

Hip flexor CSA measured for BBR subs

Iliopsoas measured at front of hip joint reduced in size while IL & PS at sacral level did not

Primarily iliacus, short deep slow twitch

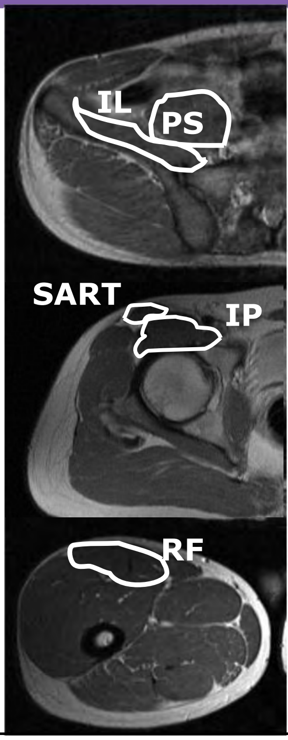
Max effect at 14 days – loss of 4.6%

RF no effect

Sart no early loss, but had lost 4.8% by day 56 BR

Belavy et al 2009

Measured volumes RF, Sartorius & Gracilis – NSD over 56 days



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Topics for Discussion

Normal function

The hip flexors & joint pathology

The hip flexors & unloading

Implications for therapeutic exercise

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Implications for exercise

Don't underestimate the importance of the hip flexors in joint protection

From Lewis et al 2009 – Exercise for weakened iliopsoas should be initiated in hip flexion to reduce anterior joint loading, esp for patients with anterior hip pain

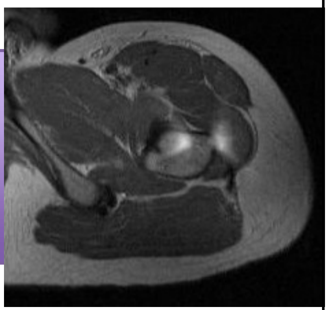
Deep iliacus fibres & iliocapsularis are likely the most important of the flexor group in local joint protection mechanisms – specificity in activation provided with RTUS

Muscle recruitment patterns will be important: Early IL

- ➡ avoid excessive TFL, increased AL activity & joint loads
- ➡ pre-set joint prior to onset of other hip flexors to reduce anterior translatory forces (Sahrmann 2002)

135

Lesson 7:
The hip adductor synergy
Function & Dysfunction



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136

Topics for Discussion

- Normal function
- The hip adductors & joint pathology
- The hip adductors & unloading
- Implications for therapeutic exercise

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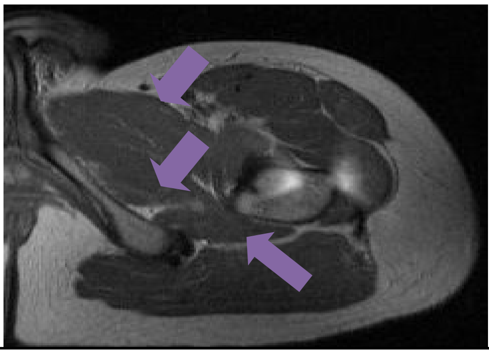
137

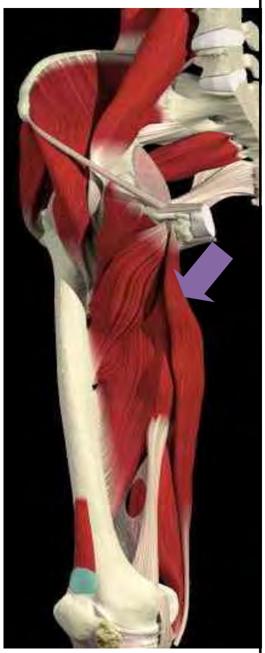
The hip adductor synergy

Superficial System –ADL, ADM, Gracilis (LGM)

Intermediate System –ADB, Pectineus?

Deep System – Quad Fem, OExt





Above Pictures © Primal Pictures Ltd

138

Adductor Magnus

Adductor

Powerful hip extensor

(Tesch & Dudley 1993 – Muscle meets magnet)

Right Picture © Primal Pictures Ltd

139

Adductor Longus

Hip adductor & flexor

Involved in balance mechanisms: Active in response to anterior translations of a forceplate in standing – posterior body sway (Henry, Fung & Horak 1998)

Close association with RA & PSymphysis

Robinson et al 2007

AL & RA attached to capsule & disk of PS in all. AB in less than 1/2

Picture © Primal Pictures Ltd

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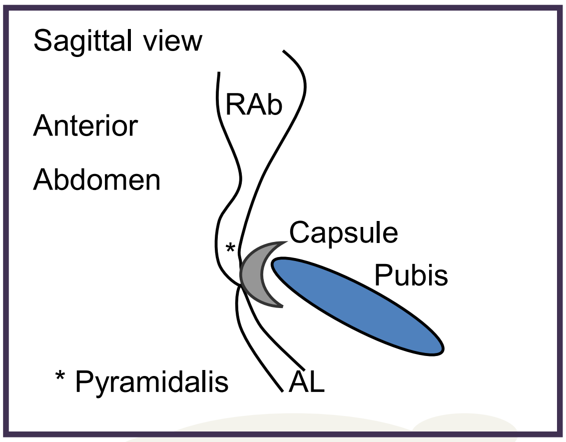
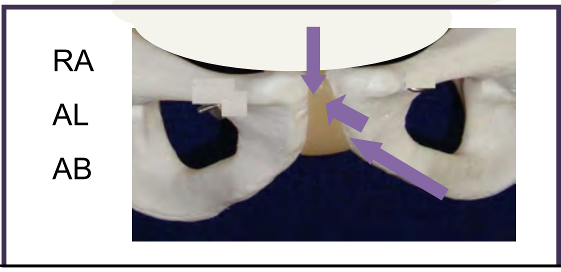
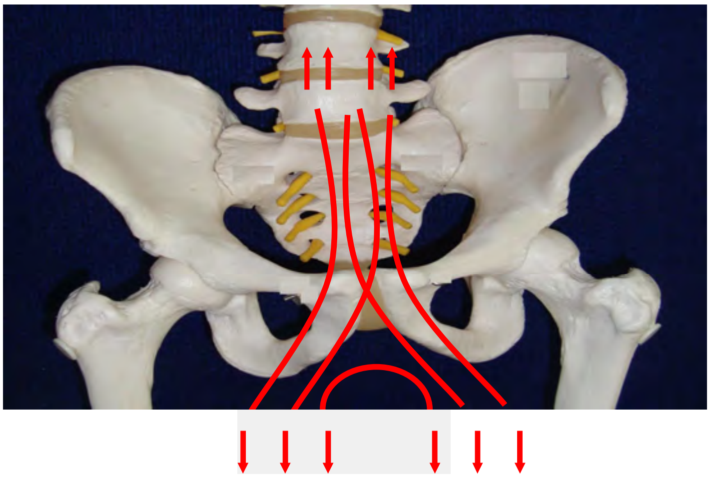
Adductor Longus Connections







See Robinson et al 2007 for cadaveric pictures & MRI's

141

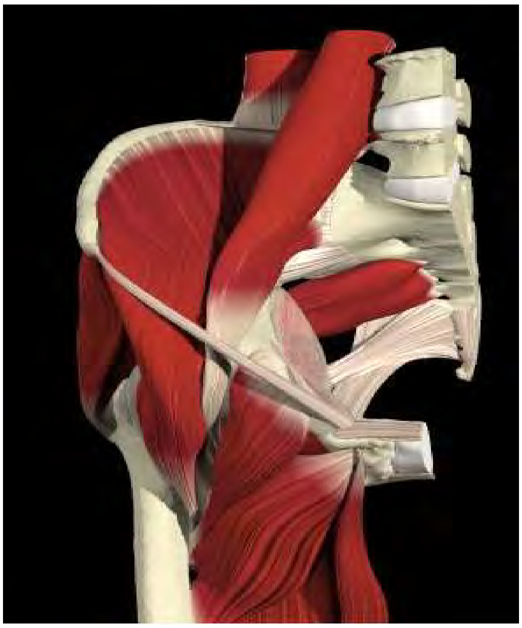
Adductor Brevis

Adductor, flexor

Assists in stabilisation of pelvis on femur in stance phase of gait

Evidence from research on CP gait & effects of surgery

(Matsuo et al 1986)



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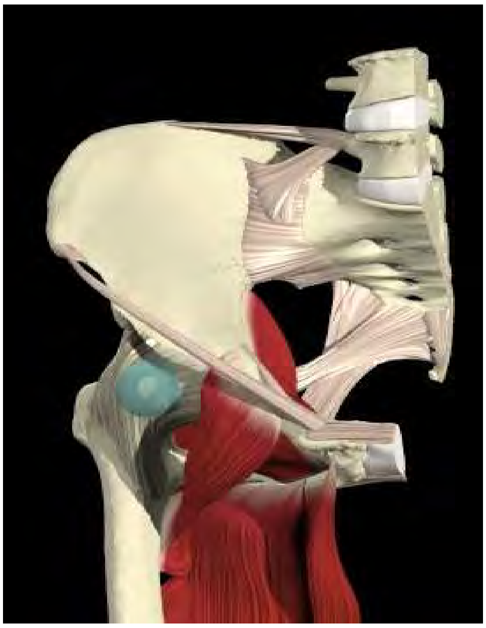
Pectineus

Hip F, Add, IR

Possibly assists in control of anterior shear of femoral head in abducted position

?Assists in positioning of pelvis over foot with adductor brevis



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Topics for Discussion

- Normal function
- The hip adductors & joint pathology
- The hip adductors & unloading
- Implications for therapeutic exercise

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Hip adductors & joint pathology

Hip joint pain/OA

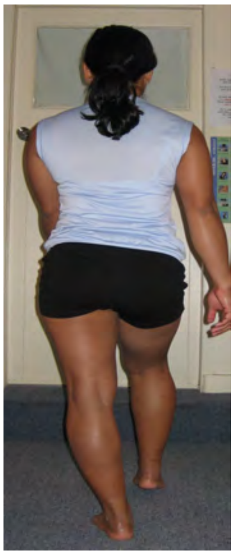
Reduced add strength - more advanced OA
(Rasch et al 2007; Arokoski et al 2002)

Increased add strength - early OA or hip pain
(Steultjens 2001, Denton 2009)
??alignment ? F weakness

Pubalgia

Add weakness predisposes to groin injury
(Tyler et al 2001) Abd:Add ratio of <0.8

Loss in strength 1-2 weeks prior to report of groin pain/Injury (Crow et al 2010)



145

Topics for Discussion

Normal function

The hip adductors & joint pathology

The hip adductors & unloading

Implications for therapeutic exercise

Picture © Primal Pictures Ltd

146

Adductors & unloading

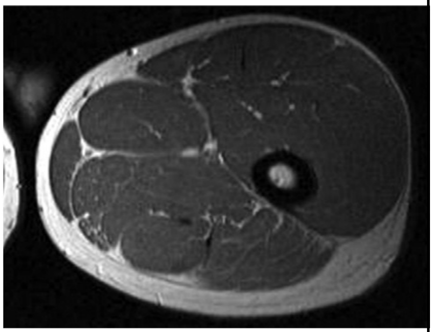
Inconclusive

Belavy et al 2009

- AM 7% loss over 56days (similar to LGM)
- AL NSD
- AB not measured

Akima et al 2007

- AL loss but not AM or AB over 20 days



147

Topics for Discussion

- Normal function
- The hip adductors & joint pathology
- The hip adductors & unloading
- Implications for therapeutic exercise

Picture © Primal Pictures Ltd

148

Implications for therapeutic exercise

Consider:

Stage of pathology

Type of pathology – hip, PS

Movement patterns – *frontal plane

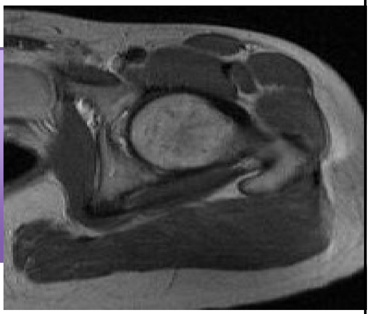
Hip abductor/adductor balance

Effects of hip flexor weakness

Strengthening Adductor Magnus as a hip extensor

149

Lesson 8:
Hip external rotators
Function & Dysfunction



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150

Topics for Discussion

- Normal function
- The external rotators & joint pathology
- The external rotators & unloading
- Implications for therapeutic exercise

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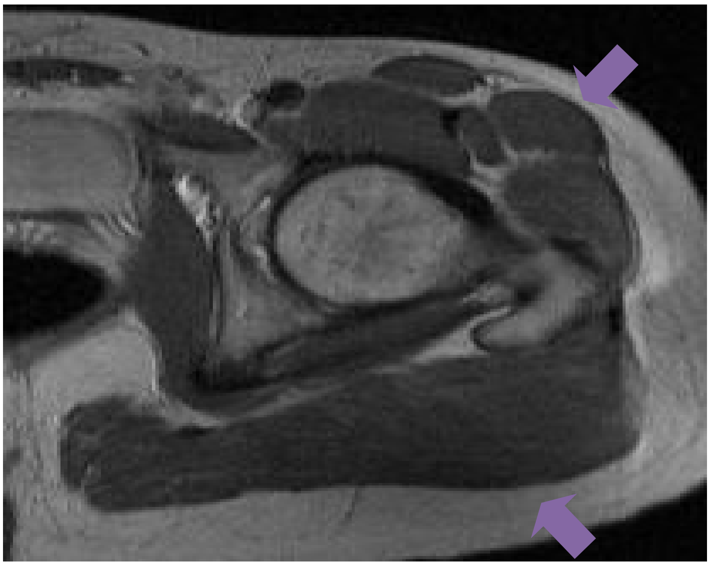
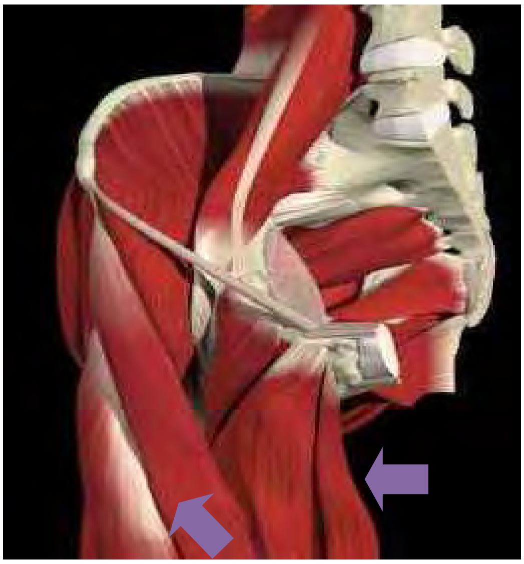
151

External rotators of the hip

Superficial System – GMax, Sart, AddM, Hams - BFLH





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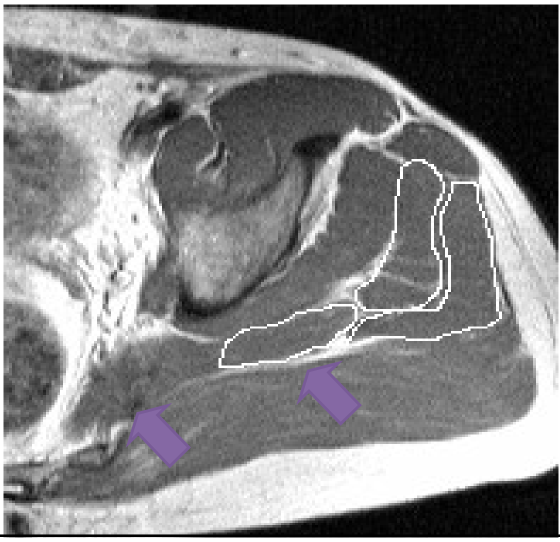
External rotators of the hip

Intermediate System – Piri & Post GMed < 45° hip flexion



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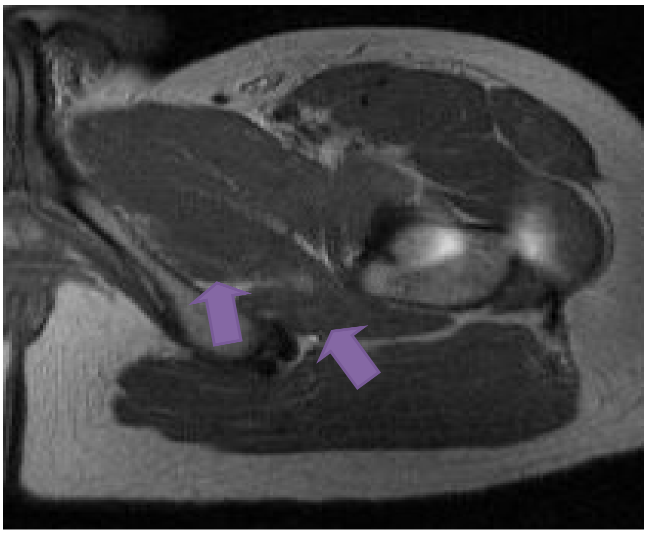
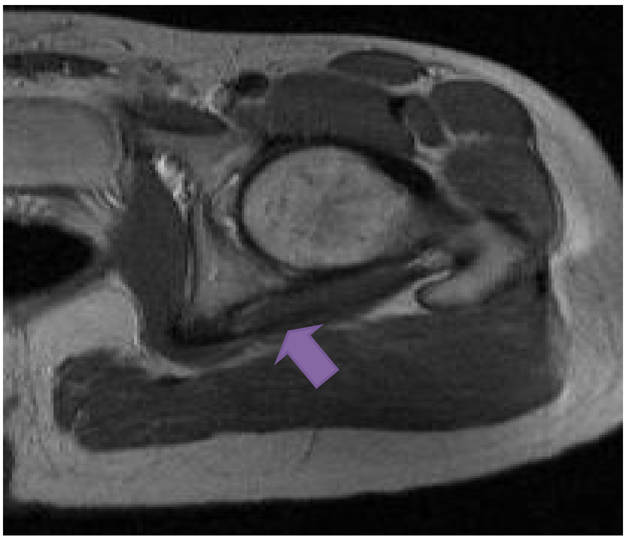
External rotators of the hip

Deep System – QF, OI, OE, Gemelli





154

Anatomical studies

Understudied

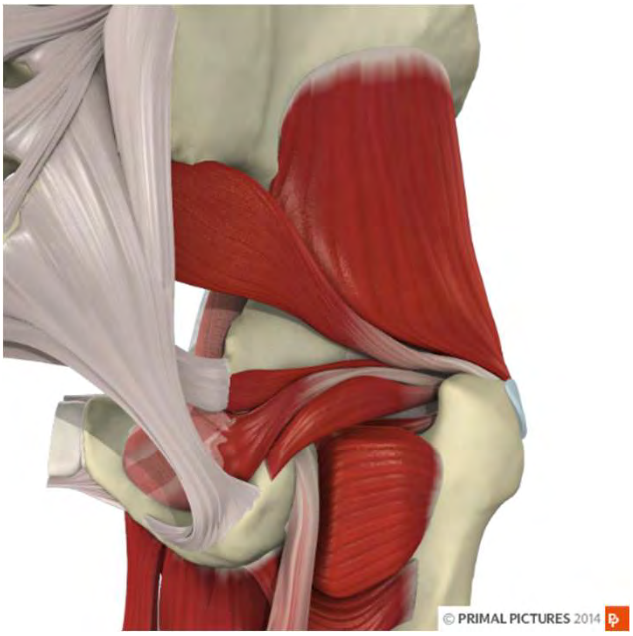
Inconsistent information

(Yoo et al 2015)

Variability in anatomy

Appears to arise during foetal development

(Naito et al 2015)



155

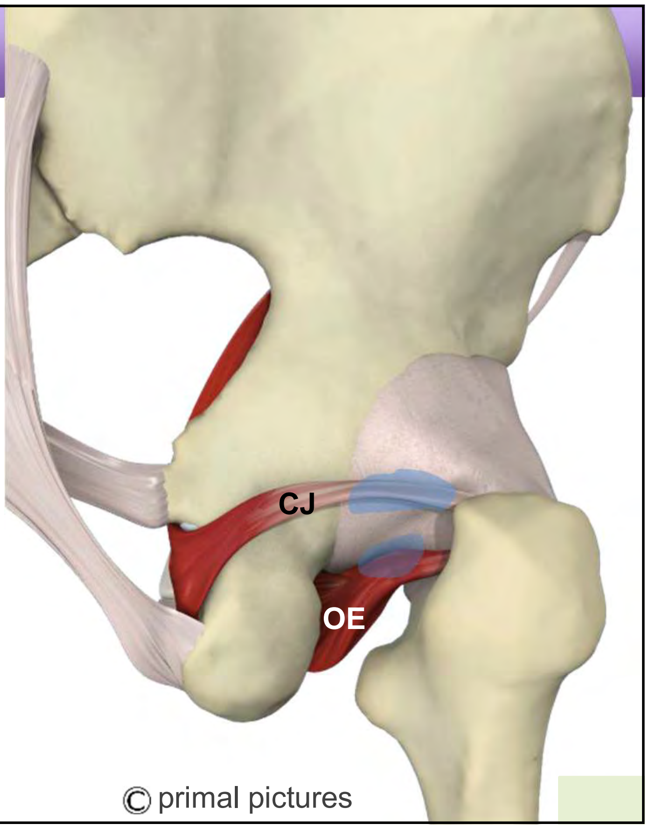
Capsular connections

CJ: Conjoint tendon – Obturator internus & gemelli

OE: Obturator Externus

Strong capsular connections

Walters et al 2014 for excellent cadaveric pictures



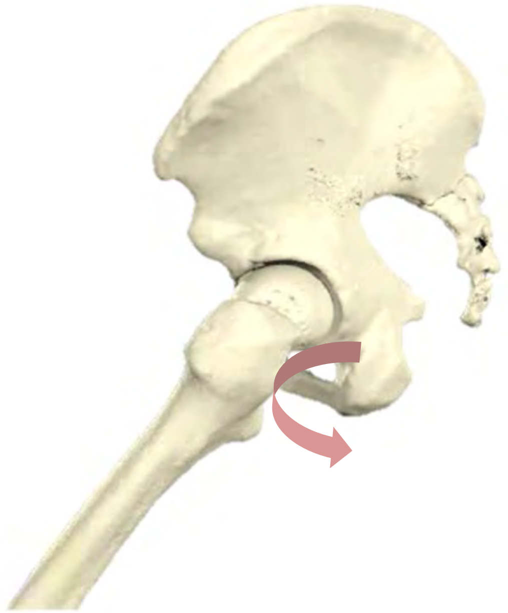
156

Anatomical modelling

Delp 1999:

GMed & Piri become internal rotators in hip F

OI, OE, QF – maintain ER moment arm through range of F



157

Anatomical modelling (Vaarbakkan et al 2015)

Quadratus Femoris

Max Strength:

Extension from a flexed hip position

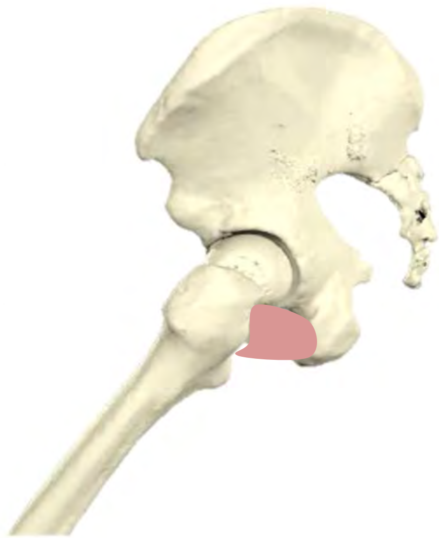
Max moment arm 60-90° F

➡ Ext & ER in synergy with GMax?

Max Length:

Superior fibres: Hip F/Add/IR

Inferior fibres: Hip F/Abd/IR



158

Anatomical modelling (Vaarbakkan et al 2015)

Obturator Externus

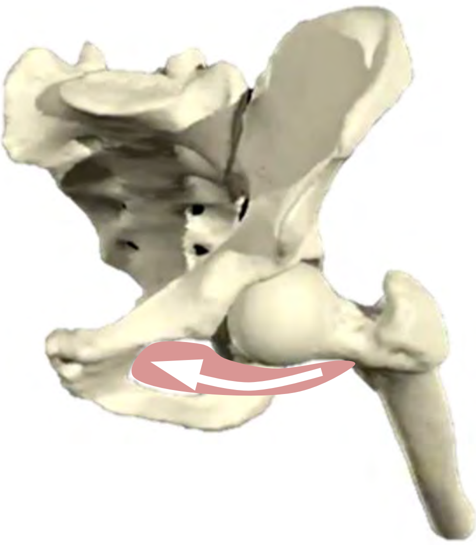
Max Strength:

Flexion & add from an extended hip position

➡ 'Locomotion-important flexing adductor'

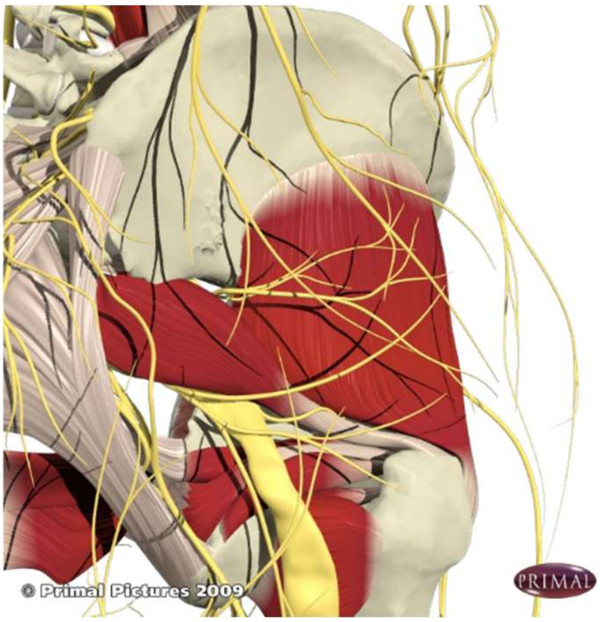
Max Length:

Hip Ext/Abd/IR



159

EMG studies



160

QF EMG (Semciw et al 2015)

MVIC's:

High: ER, Clam

Mod: Abd, Ext

Low: F, IR

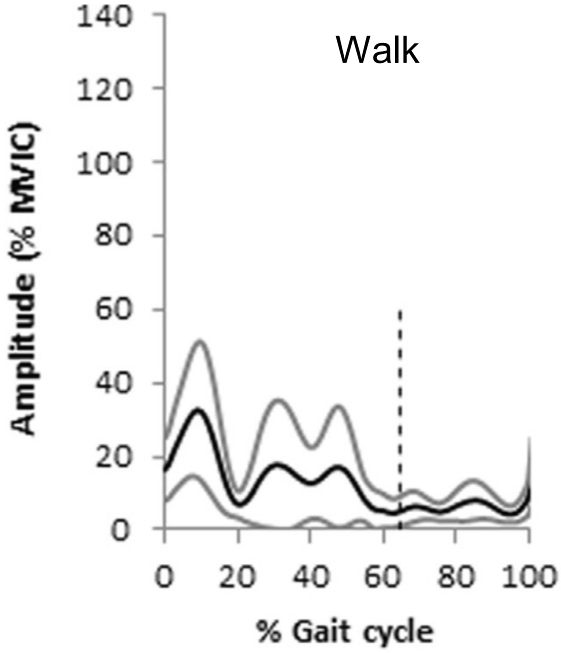
Walking:

Stance Phase:

Mod-high QF EMG

Swing Phase:

Minimal QF EMG



Journal of Biomechanics 48;p3433

161

QF EMG (Semciw et al 2015)

Running:

Stance:

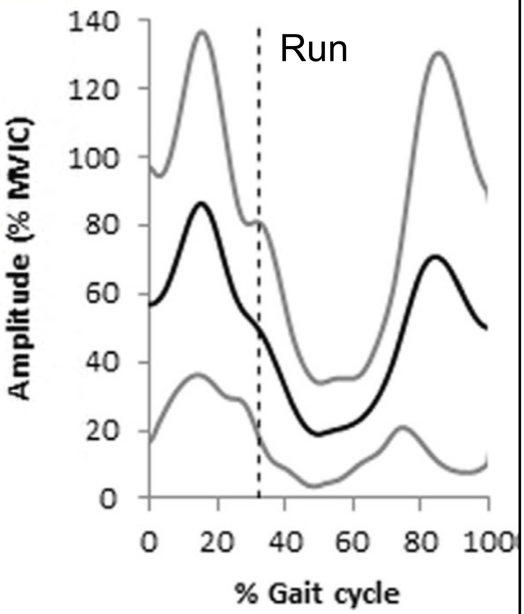
Very high EMG

Late Swing:

Very high EMG

➡ Synergistic role with post thigh muscles to decelerate in prep for stance

? Resist distraction force



Journal of Biomechanics 48;p3433

162

Obturator Internus & QF EMG

MVIC's OI & QF:

High: Ext esp at 0º

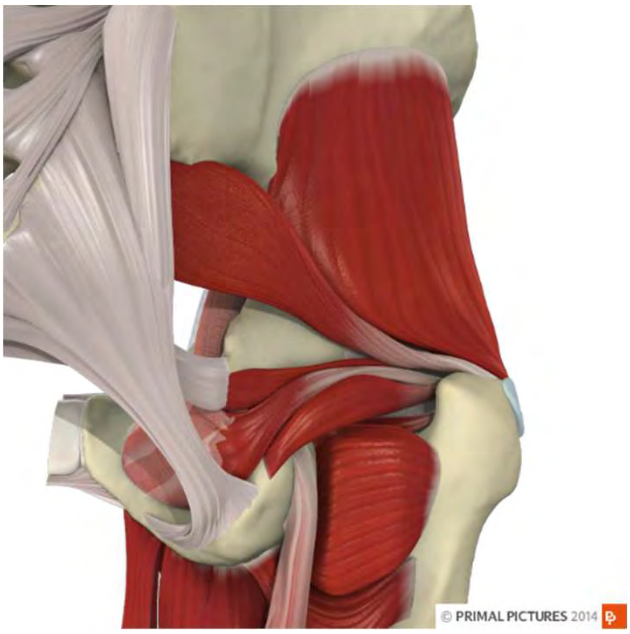
Mod: ER, Abd (Mod-low)

Low: F, IR, Add

Onset Timing OI:

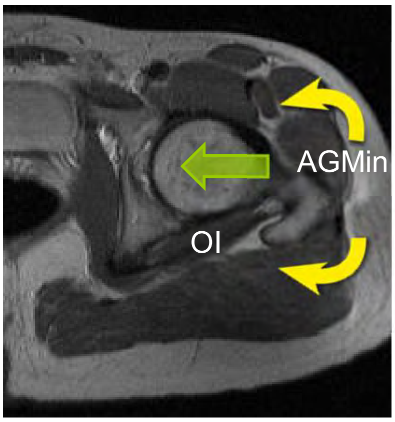
Early activation
ER, ABD, Ext

➡ likely to provide direction specific stability



163

Co-contraction of Deep Rotators



Anterior glute min & post cuff co-contract in hip extension & abduction

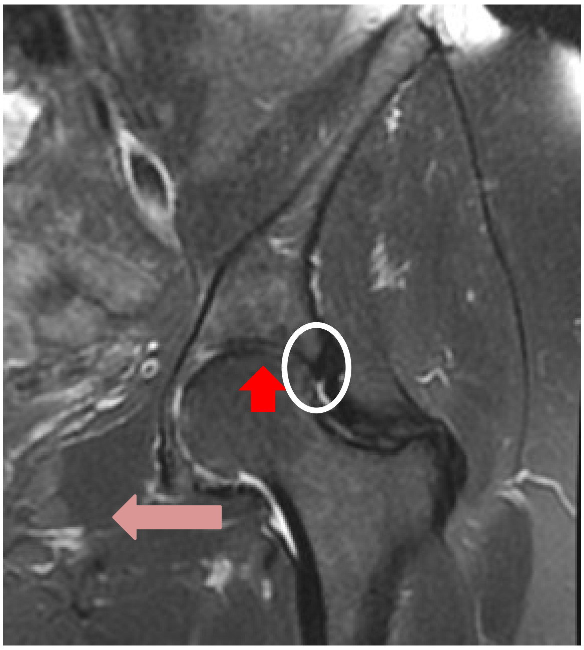
Large forces produced by both superficial extensors and abductors

Co-contraction may balance rotary function of deep int & ext rotators

- provide stability for the hip joint
- provide a stable base for larger torque producers to exert force via the greater trochanter and proximal femur (*GMax & Med)

164

Effect of ER's of load transfer across the hip joint



Weißgraeber et al 2012

Effect of activation of the deep lateral rotators on contact pressures within hip (OI, OE, Gemelli, QF, Piri)

Moves max pressure medially

Reduces pressure on lateral edge of joint

165

Topics for Discussion

Normal function

The external rotators & joint pathology

The external rotators & unloading

Implications for therapeutic exercise

Picture © Primal Pictures Ltd

166

External rotator dysfunction in hip joint pathology

Hip OA: Strength

NSD between affected and unaffected hips
(Steultjens et al 2001)

Femoracetabular Impingement: Strength

Diamond et al 2015: NSD FAI vs controls

Casartelli et al 2011: FAI 18% weaker than controls

EMG Studies:

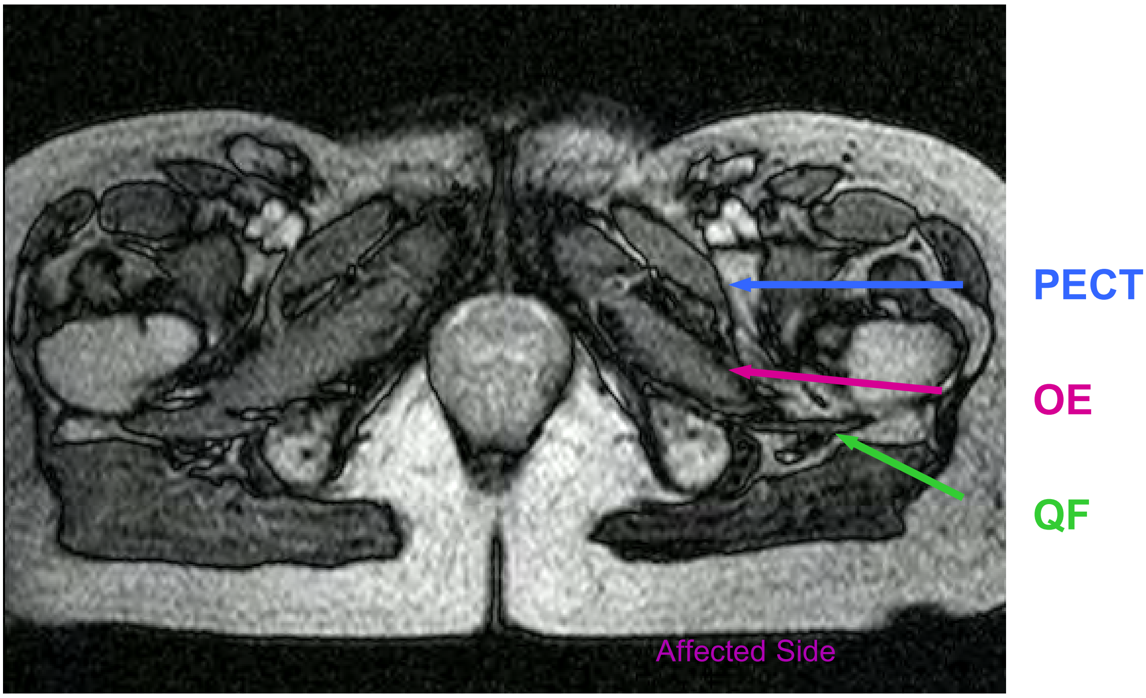
Soon to come.

Clinically: Main presentations

Underactive & weak;Overactive & weak;Overactive,not weak

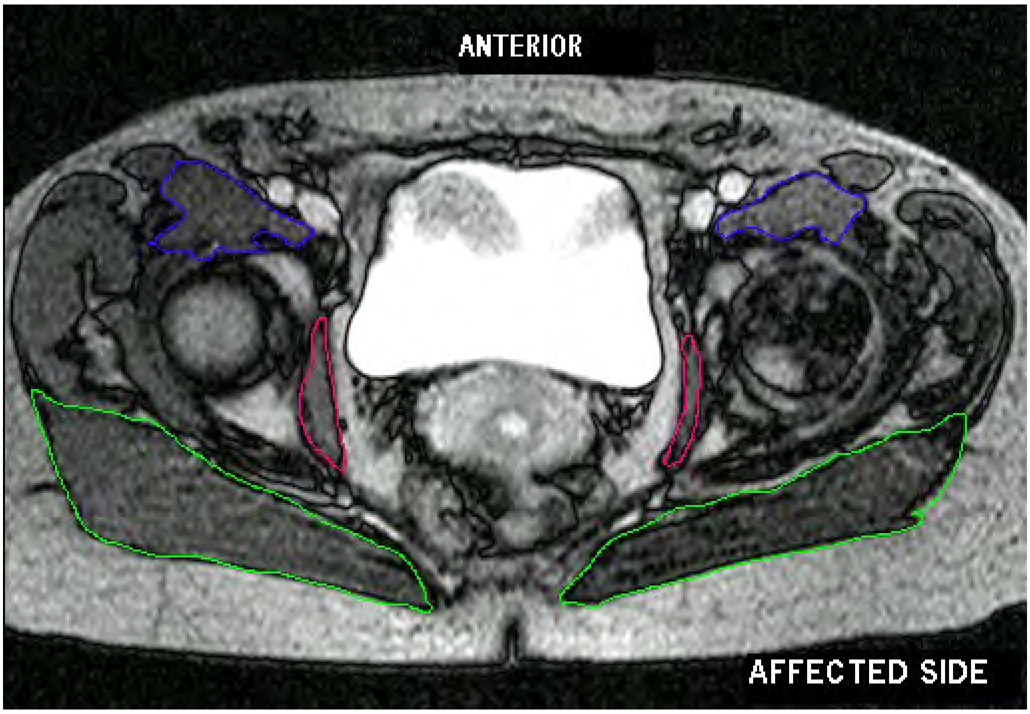
167

External rotators & hip OA



168

External rotators & hip OA



OI

GM

169

OI Tendinosis in Hip OA

Meknas et al 2011

Histological study

Degenerative change in OI tendons in pts undergoing THA

➡ Suggested a link between periarticular tendinopathy & hip OA

? Sequelae

? Contributing factor

170

Hip external rotators & Knee OA

Hinman et al 2010

ER strength in pts with med comp knee OA 27% < healthy controls

171

Hip external rotators & PFPS

Most studies have demonstrated deficits in ER strength in subjects with PFPS

Difference between normal controls and those with PFPS: 5-36% deficit

Difference between affected and unaffected sides:

2-29% deficit

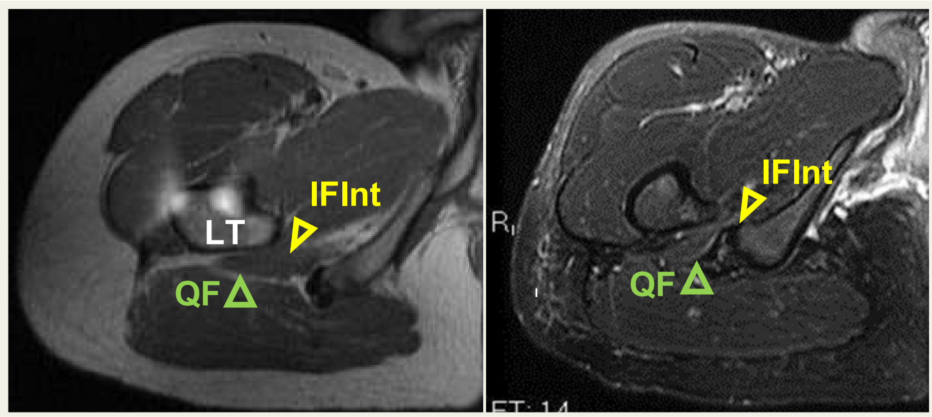
(Prins & Wurff RV 2009)

Hip Abd/ER strengthening helpful

(Khayambashi et al 2014)

172

QF Pain & Ischiofemoral Impingement

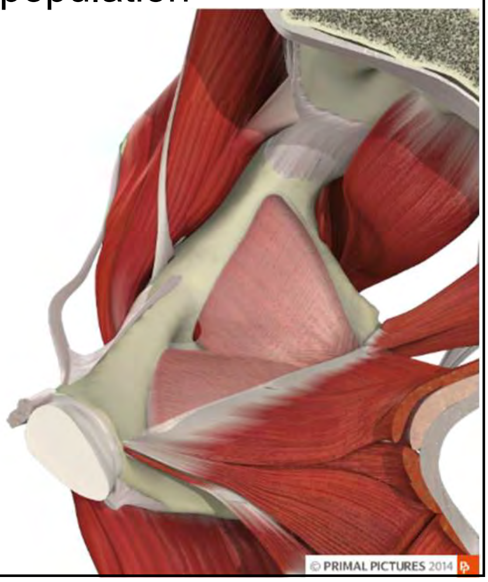


Structural: Small space between lesser troch & ischium
Soft tissue impingement of QF (Torriani et al 2009, Patti et al 2008)
Functional: Reduced IFInt assoc with excess Add/Ext/ER

173

Deep External Rotators & Pelvic Pain

Be aware of - the close relationship between OI & PF
- impact of PF hypo or hypertonicity
- effect of cueing PF in hypertonic population



174

Deep External Rotators & Pelvic Pain

Kim et al 2013

Studied effectiveness of LA Injection into OE

Presentation:
- Localised tenderness inferolateral pubic tubercle
- Pain in groin, anteromedial thigh or hip

Results: 82% good-excellent relief of pain

175

Topics for Discussion

Normal function

The external rotators & joint pathology

The external rotators & unloading

Implications for therapeutic exercise

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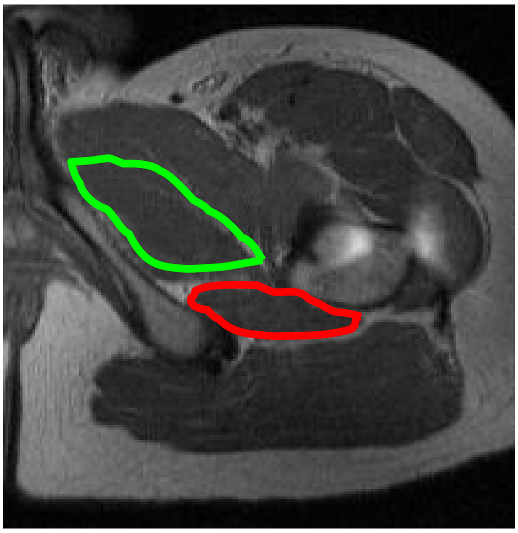
External Rotators & Unloading

Miokovic et al 2011

QF lost 9.8%(±12.2) by day 28; 18.1% (±13.3) by day 56



177

Topics for Discussion

Normal function

The external rotators & joint pathology

The external rotators & unloading

Implications for therapeutic exercise

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178

Movement Directions QF & OI

ER

EXT

60-90° F

ABD

179

Single Leg Bridge & Single Leg Squat

Semciw et al 2015

QF EMG

SL Bridge } < 20% MVIC
SL Squat

SLSquat was performed however with trunk upright

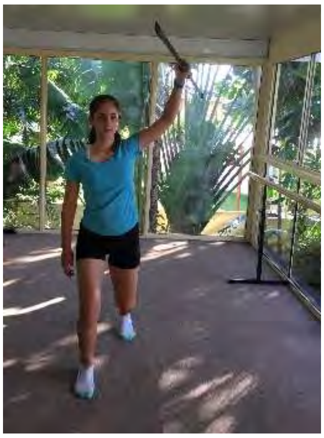
Forward lean increases activation

Consider QF/Hams synergy training

180

Other possibilities





OE:Flexor & adductor-1° function conc or ecc? Open/closed chain?

Swing phase pendulum/pawing drills may work QF & OE & hams

Perturbation may encourage variability of activation in grippers

181

Lesson 9
Summary & Conclusions

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182

Key elements for pelvic control

1. Optimal intrapelvic stability

2. Optimal control of femoral head in acetabulum

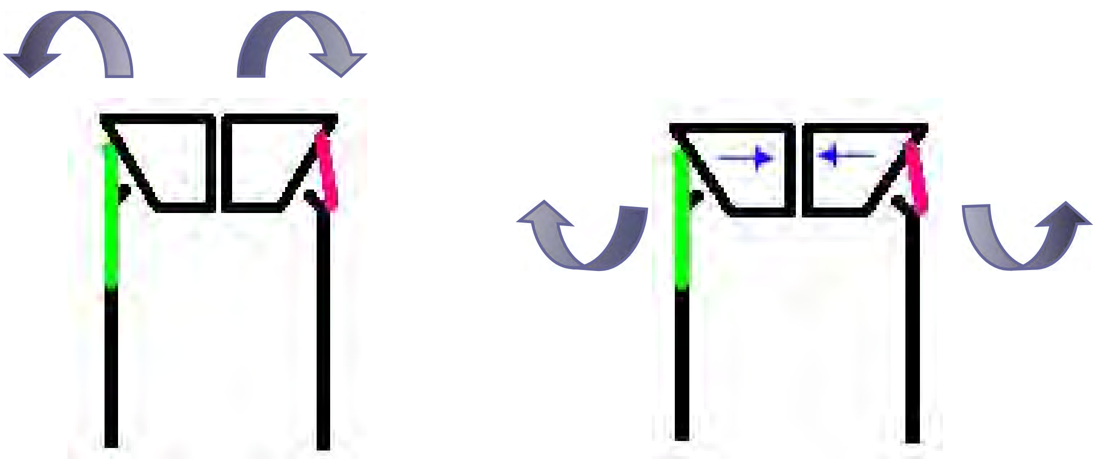
3. Optimal control of pelvis on femur

Optimal static alignment & dynamic control

183

Intrapelvic Stability

Intrapelvic stability is required to resist the bifurcating forces of the superficial muscle system



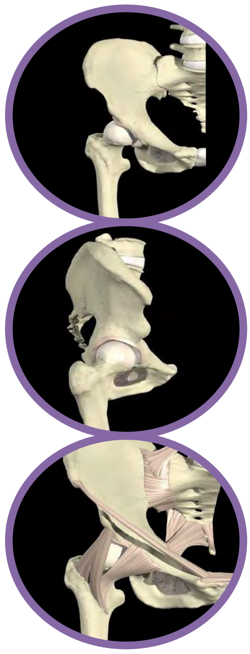
184

Stability Mechanisms of the Hip Joint

Bony structure

Labrum & negative intracapsular pressure

Capsule & ligaments



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185

Active stability system

- Helps control the femoral head in acetabulum & the pelvis on femur
- Absorbs & direct forces imposed on the hip joint & pelvis
- Inadequate muscle function/imbalance may contribute to:
  - Excessive impact loading
  - Excessive hip joint shearing/translation
  - FA Impingement

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Joint damage & migratory patterns of wear

186

Our role

Minimise negative joint loading by optimising muscle function, postural habits & movement habits

Elucidate specific dysfunction in deep, intermediate & superficial musculature

Provide targeted rehabilitation that addresses specific deficits in a manner consistent with the normal function of the target muscle/s

187

Keys for Management

Very specific functional assessment

MUST control poor postural habits and movement patterns

Specific reactivation techniques in early rehab – activate deep muscle system first. Take care not to overactivate superficial muscles including superficial portion of GMED

Closed chain exercise likely to provide more balanced muscle activation for the gluteals

Do need to progress to higher load strength & speed work to maintain normal fast twitch bias of superficial muscle system

188

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189