Getting the most bang for your exercise buck: Which exercises best activate the gluteus medius and maximus muscles?

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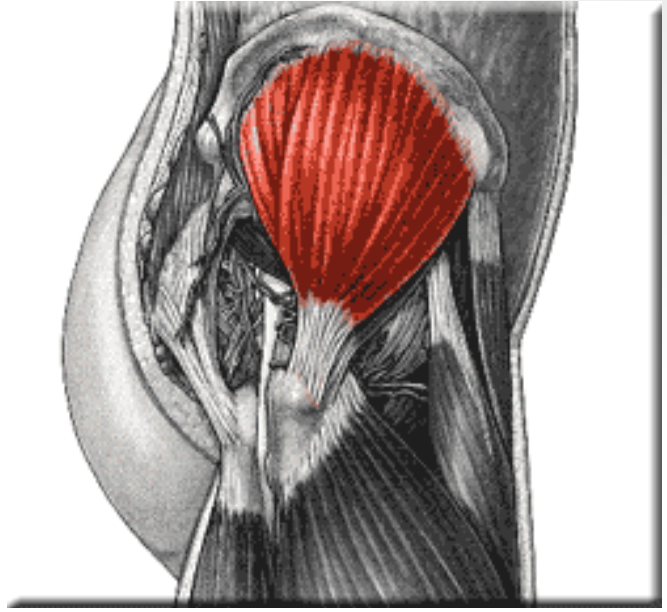
The speakers

- No conflict of interest

Objectives for today:

- Compare various gluteal strengthening exercises, and, based upon electromyographical (EMG) findings, identify which exercises preferentially activate the gluteus medius and maximus.
- Choose appropriate gluteal rehabilitation exercises based upon the patient's functional level.
- Identify which exercises demonstrate a higher percent maximal voluntary isometric contraction (%MVIC) of the gluteus medius while concurrently demonstrating a lower %MVIC of the tensor fascia latae (TFL).
- After observation, demonstrate appropriate performance of exercises for the gluteal muscles.

Gluteus Medius



- **Proximal Attachment**: Ilium (inverted “U”)
- **Distal Attachment:** lateral aspect of the greater trochanter of the femur
- **Innervation:** Superior gluteal nerve (L4, **L5**, S1)
- **Action:** Abduction of the hip, the anterior fibers MAY do hip IR; the posterior fibers definitely DO ER

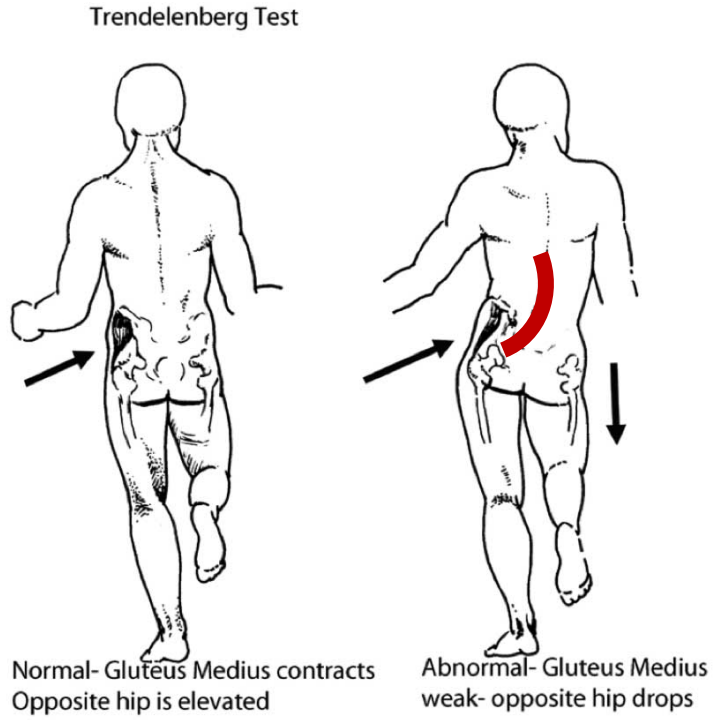
Gluteus Medius

- Accounts for 60% of abductor muscle group size (the gluteus minimus is most of the rest)
- Generates a great deal of force for its size
- Weakness is commonly seen in closed chain, where weakness results in a Trendelenburg gait, GM lurch, femoral IR, knee valgus, patella (relatively) lateral deviation, and/or midline crossover with running

Clinical Pearl

- Gluteus medius weakness from a L5 radiculopathy:
  - Gluteus medius nerve root is mostly L5
  - L5 is the most commonly involved nerve root with herniated nucleus pulposis / disc

  - Weakness of the gluteus medius will cause trendelenberg gait, resulting in lumbar sidebending to the affected side, potentially causing more narrowing of the vertebral foramen, pinching the nerve root even more…..



MMT

TFL: Abd with Flexion (or IR)

***Gluteus Medius:** Abd with extension (or ER or IR????)

Gluteus Minimus: Pure Abd

* When performing the MMT of the gluteus medius, if the muscle is weak, you might feel the patient pull the hip into flexion as you resist, using the TFL

Importance of the Gluteal Muscles in LE Function

- 15 subjects with PFP; 26% less abduction and 36% less hip ER strength
- 20 females with PFP; had 52% less hip extension strength, 27% less hip abduction strength, and 30% less hip external rotation strength
- 13 NCAA III athletes with PFP; 5 of 6 hip muscles tested were weaker than sport-matched controls

Robinson et al, JOSPT, 2007

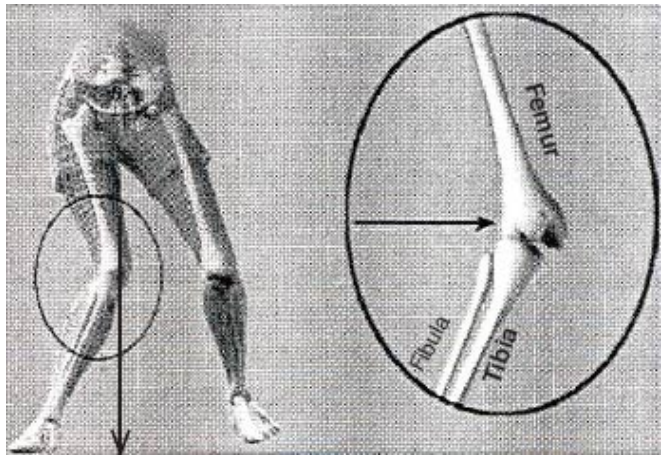
Ireland, JOSPT, 2003

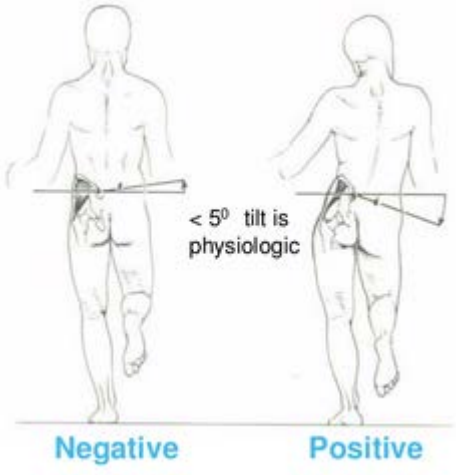
Cichanowski, MSSE, 2007

Clearly

- The need for a strong gluteus medius (with good neuromuscular control and appropriate timing) is essential

- In addition, other hip abductors (the TFL) may need to be quieted, as the TFL will cause the femur to internally rotate, which leads to PFP, knee valgus, whole limb pronation, etc.





Which Exercises?

First…….

- EMG is typically expressed as a %MVIC (percentage of the maximal voluntary isometric contraction)
  - Low-level muscle activation: 0–20% MVIC
  - Moderate-level activation: 21–40% MVIC
  - High-level activation: 41–60% MVIC
  - Very high-level activation: > 60% MVIC

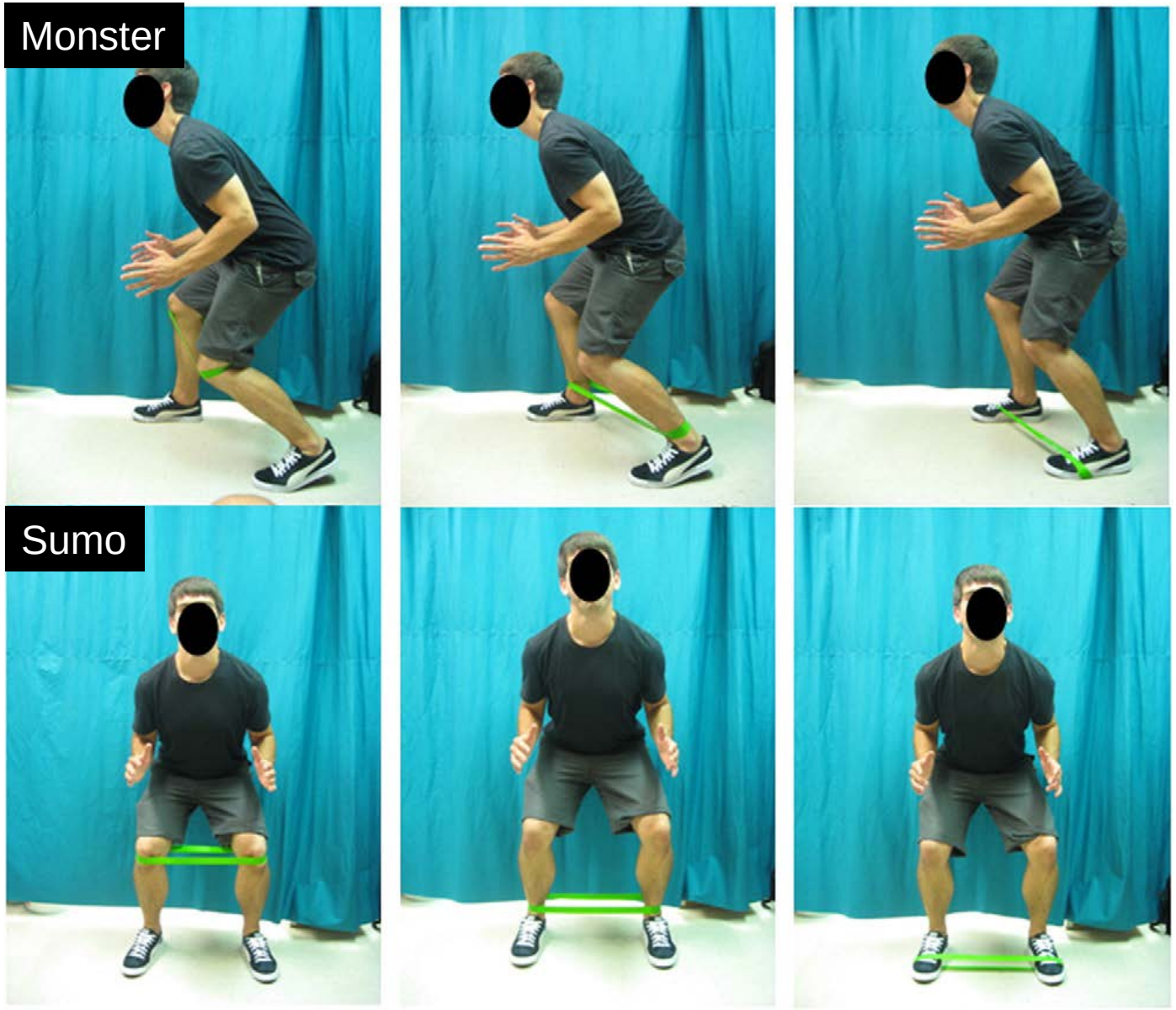
- Contaminate the desired muscle's EMG signal with that of nearby muscles (i.e., cross-talk)

Escamilla, JOSPT, 2010

Location of Resistance Bands

- Surface EMG
- 9 males
- GMED, GMAX and TFL
- Three resistance band placements during ‘Monster Walks’ and ‘Sumo Walks’
  - Around the knees
  - Around the ankles
  - Around the feet

Cambridge, Clin Biomech, 2012



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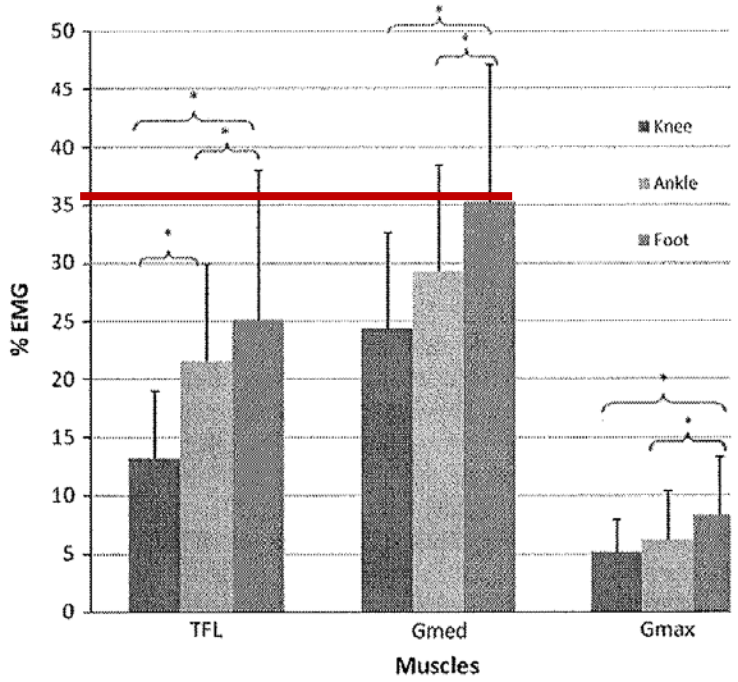


Fig. 4. Mean EMG Sumo walks is shown here with error bars set to the respective SD. A progressive activation is observed in general with the GMed activation. Notice the pattern TFL does not show a significant increase with the foot placement; while the GMax only increases significantly with the foot placement. *Statistical significant difference.

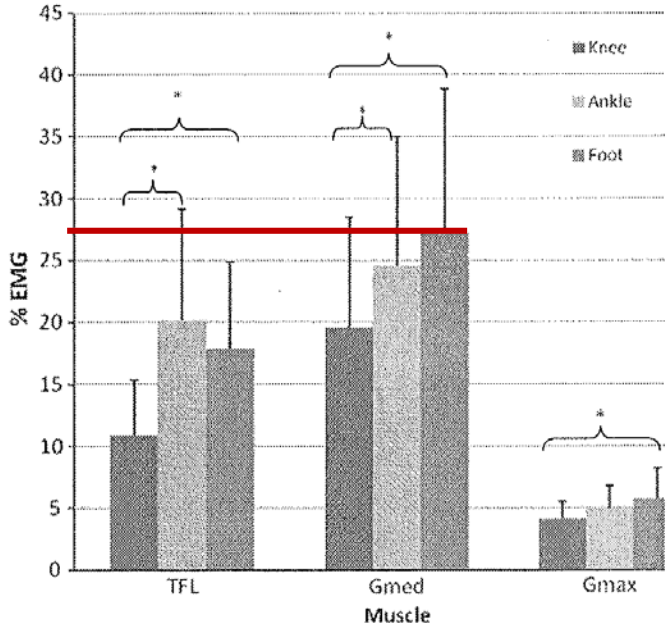


Fig. 5. Mean EMG for the Monster walk exercise is shown here with error bars set to the respective SD. Monster walks demonstrates the progressive nature of the activation patterns. Generally, GMed increases with distal band placement, while TFL is unaffected with the foot placement and GMax only increases with the foot placement. *Statistical significant difference.

Sumo (frontal)

Monster (sagittal)

"Moderate" Category

Location of Resistance Bands

- **GMED** activation progressively increased when moving the band distally

- **THM:** placing the band around the forefoot selectively enhanced gluteal muscle activation versus TFL (ER)

Cambridge, Clin Biomech, 2012

4-way hip (stance AND moving limb)

- Surface EMG
- 26 active and healthy people
- GMED and GLUT MAX
- 4-way hip motions and stance and moving limb

Youdas, J Sport Rehabil, 2014

Table 3 Comparison of Gluteus Medius Muscle Activation Levels (% Maximum Voluntary Isometric Contraction [MVIC]) Between the Moving and Stance Limbs During Hip-Joint-Strengthening Exercise Using Elastic-Tubing Resistance, Mean ± SD

Exercise	Moving-limb %MVIC	Stance-limb %MVIC	*P*
Cross-over	14.9 ± 17.7	13.1 ± 12	.653
Reverse cross-over	52.9 ± 17.6†	50.0 ± 25.1¶	.560
Front pull	16.7 ± 16.2	29.1 ± 19.9§	.025*
Back pull	30.7 ± 19.7‡	31.4 ± 22.1§	.887

*Gluteus medius recruitment is greater in the stance limb than in the moving limb when performing the front-pull exercise.

†For the moving limb, gluteus medius muscle recruitment is greater for the reverse cross-over exercise than for the cross-over, front-pull, and back-pull exercises ($P < .001$).

‡For the moving limb, gluteus medius muscle recruitment is greater in the back-pull exercise than in the cross-over ($P = .001$) and front-pull exercise ($P = .007$).

¶For the stance limb, gluteus medius muscle recruitment is greater for the reverse cross-over than for the cross-over, front-pull, and back-pull exercises ($P < .001$).

§For the stance limb, gluteus medius muscle recruitment is greater for the back-pull and front-pull exercises than for the cross- over exercise ($P < .001$).

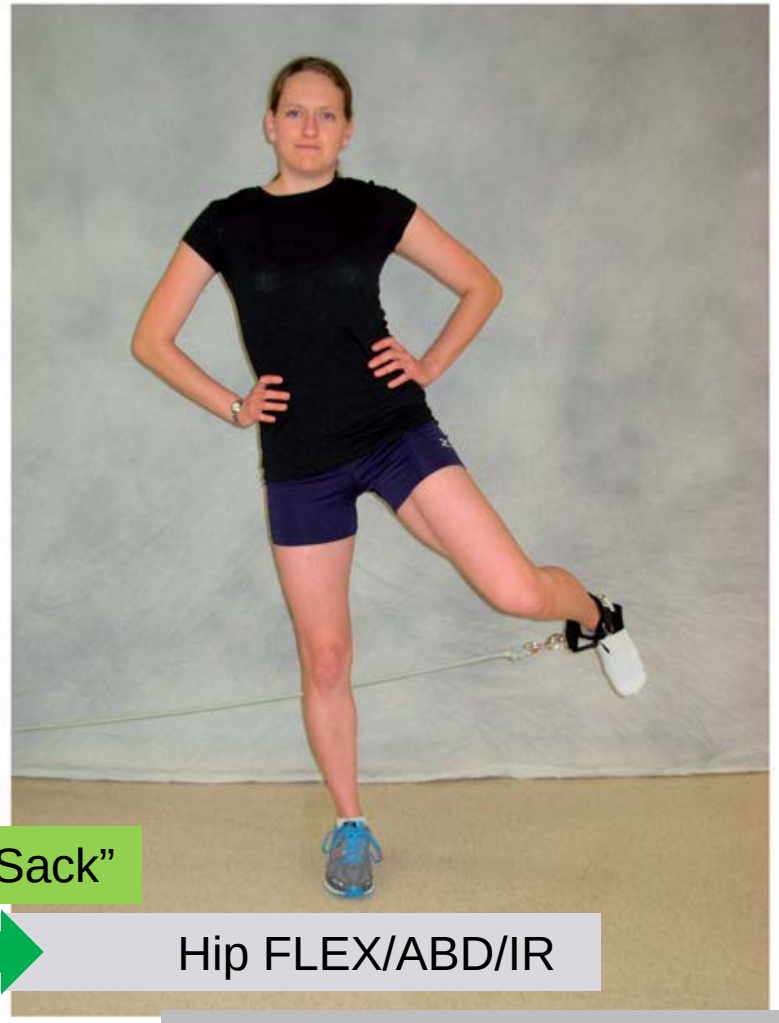
Youdas, J Sport Rehabil, 2014

GMED activity with PNF + Resistance

- Surface EMG
- 26 healthy participants
- Moving and stance limbs during 4 LE PNF patterns with resistance

Youdas, Physiother Theory Pract, 2015

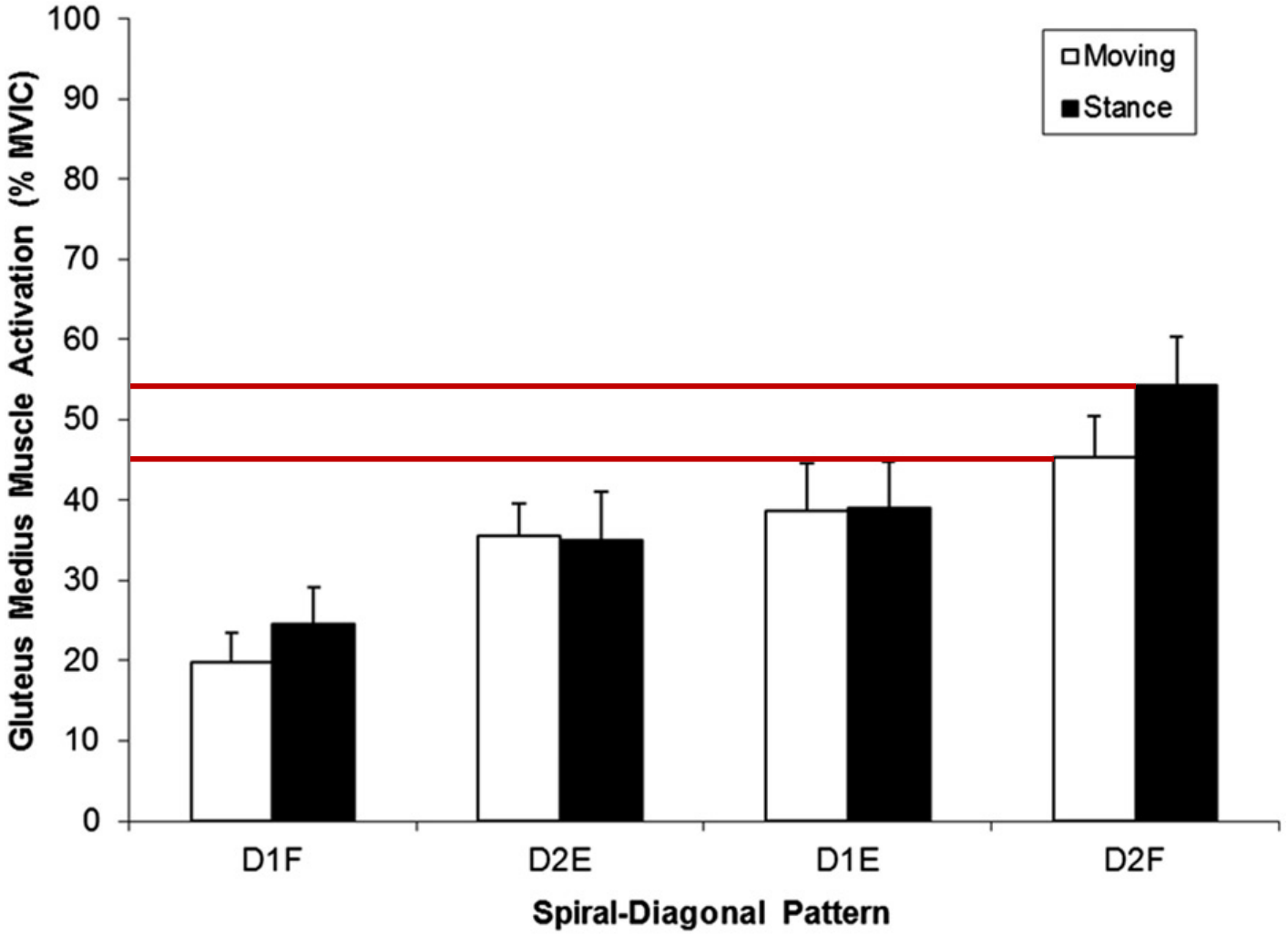
GMED activity with PNF + Resistance



"Hacky Sack"

Hip ADD/ EX/ ER → Hip FLEX/ABD/IR

Youdas, Physiother Theory Pract, 2015



- THM: If using PNF, use D2F

"High" Category

Youdas, Physiother Theory Pract, 2015

Jump-landing-jump +/- resistance

- Surface EMG
- 13 males and 15 females (19-23 years)
- Subjects performed jump–landing–jump tasks with or without a resistance band applied to their ankles

Dai, J Biomech, 2014

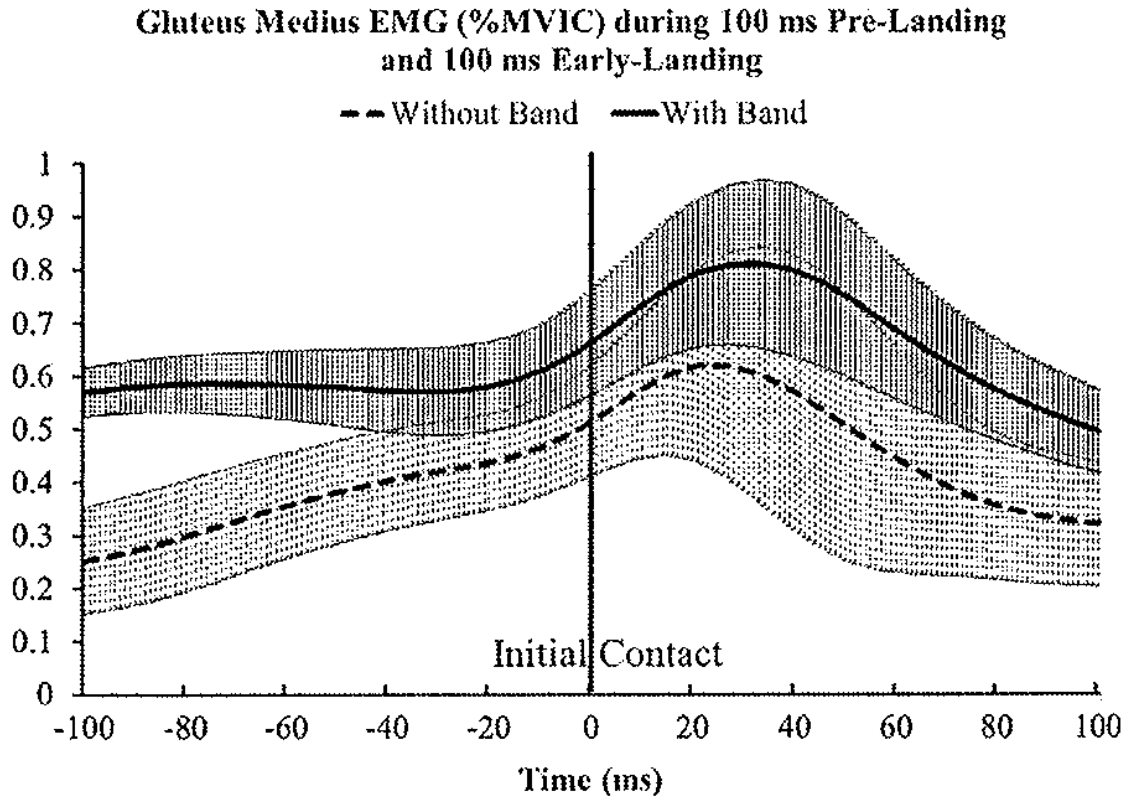


Fig. 6. Gluteus medius EMG (% MVIC) during pre-landing (100 ms before initial contact) and early-landing (100 ms after initial contact). Lines represent the ensemble means. Error bars represent 1.96* standard errors of the means.

- THM: Use a band with jump landing techniques

Dai, J Biomech, 2014

EMG of GMED in 5 exercises

- Surface EMG
- 20 healthy subjects (age 21-30)
- GMED activation during 5 exercises:
  - double limb stance (DLSt)
  - single limb stance (SLSt)
  - single limb squat (SLSq)
  - single limb stance on unstable surface (SLSt-U)
  - single limb squat on unstable surface (SLSq-U)

Krause, J Strength Cond Res, 2009

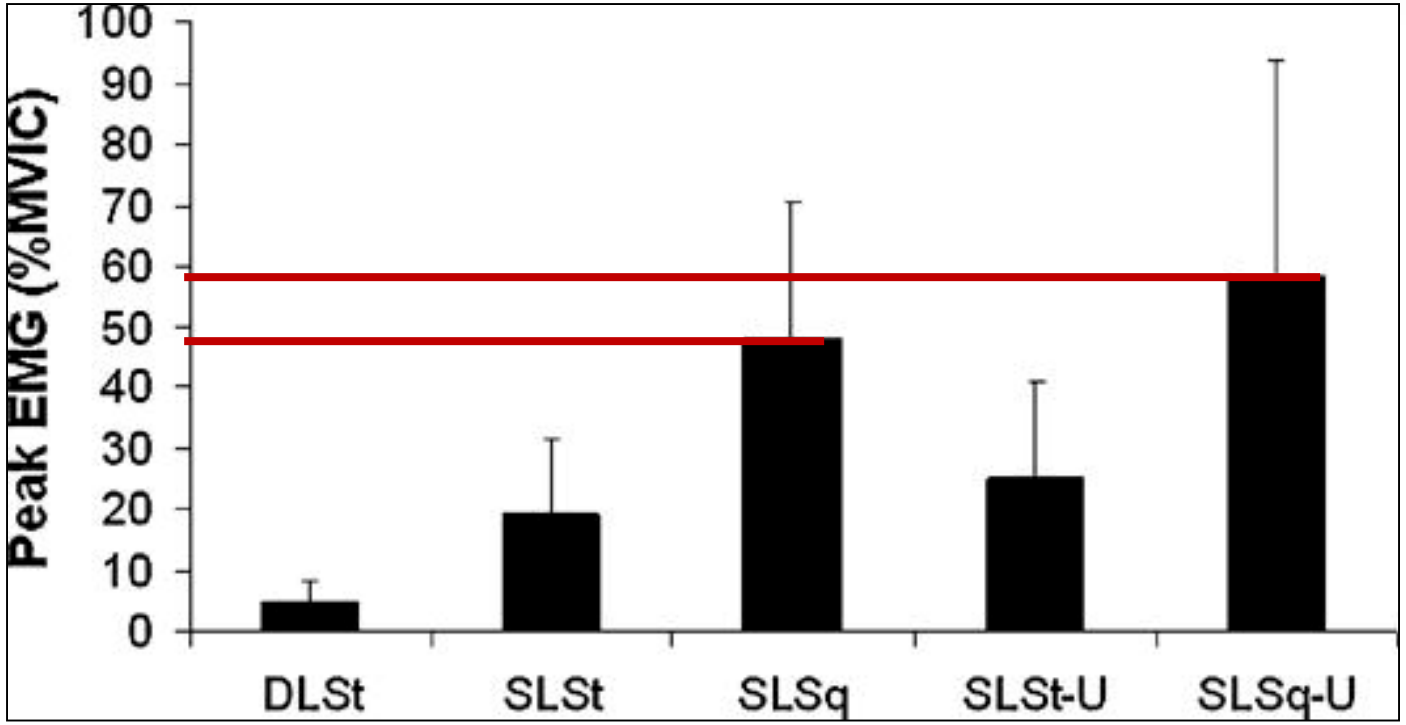


Figure 6 . Mean peak electromyography (EMG) for 5 test conditions as MVIC%. Five test conditions included double limb stance (DLSt), single limb stance (SLSt), single limb squat (SLSq), single limb stance on unstable surface (SLSt-U), and single limb squat on unstable surface (SLSq-U). Single limb exercises resulted in significantly greater GMEd activity compared with double limb stance. Single limb squat exercise produced significantly greater GMed EMG activity compared with single limb stance. No significant difference was found in Gmed EMG between like exercises on unstable as compared with stable surface.

Krause, J Strength Cond Res, 2009

"High" Category

4 step-up variations

- Surface EMG
- 15 healthy females
- GMED, GMAX, biceps femoris(BF), rectus femoris, semitendinosus (ST), vastus lateralis, and vastus medialis(VM)
- 4 step-ups exercises
  - step-up
  - crossover step-up
  - diagonal step-up
  - lateral step-up

Simenz, J Strength Cond Res, 2012

Table 4. RMS EMG data for GMe, expressed as a percentage of MVIC for each 6RM during eccentric and concentric phases of 4 step-up variations ($N = 14$).*

Eccentric phase	Step-up†‡ 41.90 ± 15.04	Diagonal step-up‡§‖ 40.41 ± 14.80	Crossover step-up†‡ 38.39 ± 15.66	Lateral step-up†§‖ 36.46 ± 15.10
Concentric phase	Crossover step-up†‡ 76.47 ± 23.40	Step-up†‡ 69.57 ± 16.75	Diagonal step-up‡§‖ 65.87 ± 15.73	Lateral step-up†‡‖ 54.66 ± 13.77

*RMS = root mean square; EMG = electromyography; MVIC = maximal voluntary isometric contraction; GMx = gluteus maximus; RM = repetition maximum.
†Significantly different from diagonal step-up ($p \leq 0.05$).
‡Significantly different from lateral step-up ($p \leq 0.05$).
§Significantly different from step-up ($p \leq 0.05$).
‖Significantly different from crossover step-up ($p \leq 0.05$).

"Very High" Category

Simenz, J Strength Cond Res, 2012

GMED activation

- Surface EMG
- 21 healthy, physically active subjects
- GMED and GMAX activation during 12 different exercises

DiStefano, JOSPT, 2009

TABLE 2

Normalized Gluteus Medius Mean Signal Amplitude (% MVIC)

Exercise	Mean ± SD (95% CI)
Side-lying hip abduction	81 ± 42 (62, 101)
Single-limb squat	64 ± 24 (53, 75)
Lateral band walk	61 ± 34 (46, 76)
Single-limb deadlift	58 ± 25 (47, 70)
Sideways hop	57 ± 35 (41, 73)
Transverse hop*	48 ± 25 (37, 59)
Transverse lunge*	48 ± 21 (38, 57)
Forward hop*	45 ± 21 (38, 57)
Forward lunge*†	42 ± 21 (33, 52)
Clam with 30° hip flexion*	40 ± 38 (23, 57)
Sideways lunge*†	39 ± 19 (30, 47)
Clam with 60° hip flexion*†	38 ± 29 (25, 51)

Abbreviations: CI, confidence interval; MVIC, maximum voluntary isometric contraction.
* *Exercises are significantly different than the hip abduction exercise* ($P<.05$).
† *Exercises are significantly different from the single-limb squat* ($P<.05$).

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FIGURE 5. Lateral band walks.

FIGURE 2. Middle position for side-lying hip abduction exercise.

Top 3 Exercises

FIGURE 3. Single-limb squat exercise.

"Very High" Category

DiStefano, JOSPT, 2009

GMED Activation, Take 2

- Surface EMG
- 24 healthy subjects
- GMED and GMAX activation during 18 exercises

Boren, Int J Sports Phys Ther, 2011

Table 4.

Results for Gluteus Medius recruitment, %MVIC and rank for all exercises.

Exercise condition	# Subjects Included for analysis	%MVIC Gluteus Medius	Rank Gluteus Medius
Side plank abd, DL down	21	103.11	1
Side plank abd, DL up	22	88.82	2
Single limb squat	22	82.26	3
Clamshell (Hip Clam) 4	23	76.88	4
Front plank with Hip Ext	23	75.13	5
Clamshell (Hip Clam) 3	22	67.63	6
Side-lying abd	23	62.91	7

"Very High" Category

Boren, Int J Sports Phys Ther, 2011


Side Plank with Abduction:
dominant leg down (103.11% MVIC) #1
dominant leg up (88.82% MVIC) #2
Start with subject in a side plank position with shoulders, hips, knees, and ankles in line, and then to rise to plank position. The subject is allowed upper extremity support as seen. While balancing on elbows and feet, the subject raises the top leg into abduction for one beat and then lowers leg for one beat.
Subject maintains plank position throughout all repetitions

Boren et al, Int J Sports Phys Ther, 2011

"Very High" Category

Single Limb Squat (82.26% MVIC) #3
Subject stands on the dominant leg, slowly lowering the buttocks to touch a chair 47cm (~18 in.) for two beats and then extends back to standing for two beats.

"Very High" Category

Boren, Int J Sports Phys Ther, 2011

Clamshell (hip clam) Progression (76.88% MVIC) #4
The subject is sidelying on the non-dominant side. The subjects hip is fully extended and the subject maintains the height of the knee and internally rotates at the hip by bringing the foot toward the ceiling for one beat and returns to the start position with knee and ankle in line during the next beat.

"Very High" Category

Boren, Int J Sports Phys Ther, 2011

Front Plank with Hip Extension: (75.13% MVIC) #5
Prone plank with neutral alignment. Subject lifts the dominant leg off of the ground, flexes the knee of the dominant leg, and extends the hip past neutral hip alignment by bringing the heel toward the ceiling for one beat and then returns to parallel for one beat.

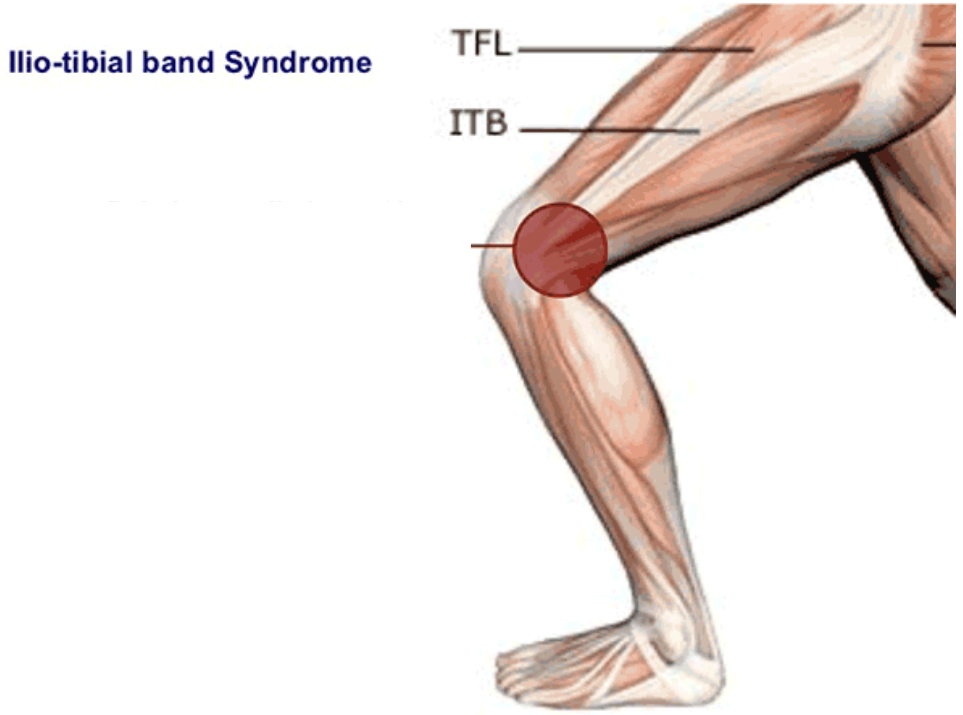
"Very High" Category

Boren et al, Int J Sports Phys Ther, 2011

The TFL

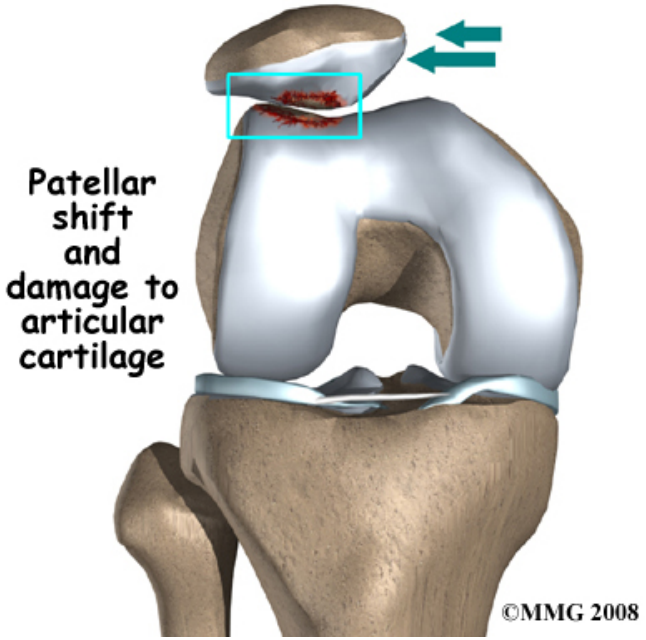
- The TFL is an abductor and an internal rotator of the hip.

- It has a distal attachment via fibrous slips to the superior and lateral patella



Importance of a quiet TFL!

- A tight ITB/ increased muscle activation in the TFL can exert a lateral force on the patella, resulting the patella shifting laterally, causing improper loading on the undersurface of the patella



GMED and GMAX with a quiet TFL

- **Fine-wire EMG**
- 20 healthy subjects
- GMED, GMAX, TFL
- 11 different exercises
- A descriptive gluteal-to-TFL muscle activation index was used to identify preferred exercises for recruiting the gluteal muscles while minimizing TFL activity.

Selkowitz, JOSPT, 2013

TABLE 1 NORMALIZED ELECTROMYOGRAPHIC AMPLITUDE OF EACH MUSCLE FOR EACH EXERCISE*

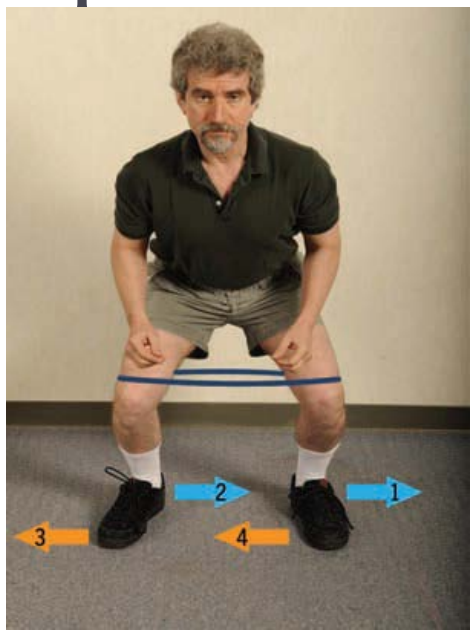
Exercise	Tensor Fascia Lata	Gluteus Medius	Superior Gluteus Maximus
Sidelying hip abduction	32.3 ± 13.1	43.5 ± 14.7 (*P* = .012)†	23.7 ± 15.3 (*P* = .033)†
Bilateral bridge	8.2 ± 7.4	15.0 ± 10.5 (*P* = .011)†	17.4 ± 11.9 (*P* = .008)†
Clam	11.4 ± 11.4	26.7 ± 18.0 (*P* = .006)†	43.6 ± 26.1 (*P*<.001)†
Hip hike	31.4 ± 14.4	37.7 ± 15.1 (*P* = .196)	17.7 ± 15.2 (*P* = .001)‡
Lunge	21.6 ± 14.5	19.3 ± 12.9 (*P* = .623)	20.1 ± 11.1 (*P* = .728)
Quadruped hip extension, knee extending	15.6 ± 9.3	27.3 ± 14.9 (*P*<.002)†	28.5 ± 16.6 (*P*<.007)†
Quadruped hip extension, knee flexed	18.7 ± 10.6	30.9 ± 15.2 (*P* = .001)†	30.1 ± 12.5 (*P* = .012)†
Sidestep	13.1 ± 7.1	30.2 ± 15.7 (*P* = .002)†	27.4 ± 16.7 (*P* = .002)†
Squat	4.6 ± 3.8	9.7 ± 7.3 (*P* = .017)†	12.9 ± 7.9 (*P*<.001)†
Step-up	21.4 ± 11.4	29.5 ± 14.9 (*P* = .065)	22.8 ± 15.6 (*P* = .754)
Unilateral bridge	18.1 ± 12.9	30.9 ± 20.7 (*P* = .007)†	34.6 ± 16.8 (*P* = .001)†

**Values are mean ± SD percent maximum voluntary isometric contraction.*
†Significantly greater than tensor fascia lata (P<.05).
‡Significantly less than tensor fascia lata (P<.05).

Selkowitz, JOSPT, 2013

Top 5 exercises for GMED with a quiet TFL

- CLAM
- SIDESTEP
- UniBRG
- QKE
- QKF



WB leg

NWB leg

Selkowitz, JOSPT, 2013

GMED and GMAX with a quiet TFL

- Surface EMG
- 20 healthy university students
- GMED and TFL
- Hip abduction in neutral (N), with medial rotation (MR), and with lateral rotation (LR)
- GMED activation was higher with MR than N or LR
- TFL activation was higher with LR than N
- Hip Abduction with MR had the best GMED:TFL ratio

Lee, J Sport Rehabil, 2013

Table 2 Comparison of Muscle Activity in the Gluteus Medius and the Tensor Fasciae Latae Among Different Hip Rotations During Side-Lying Hip Abduction (SHA), Mean (SD)

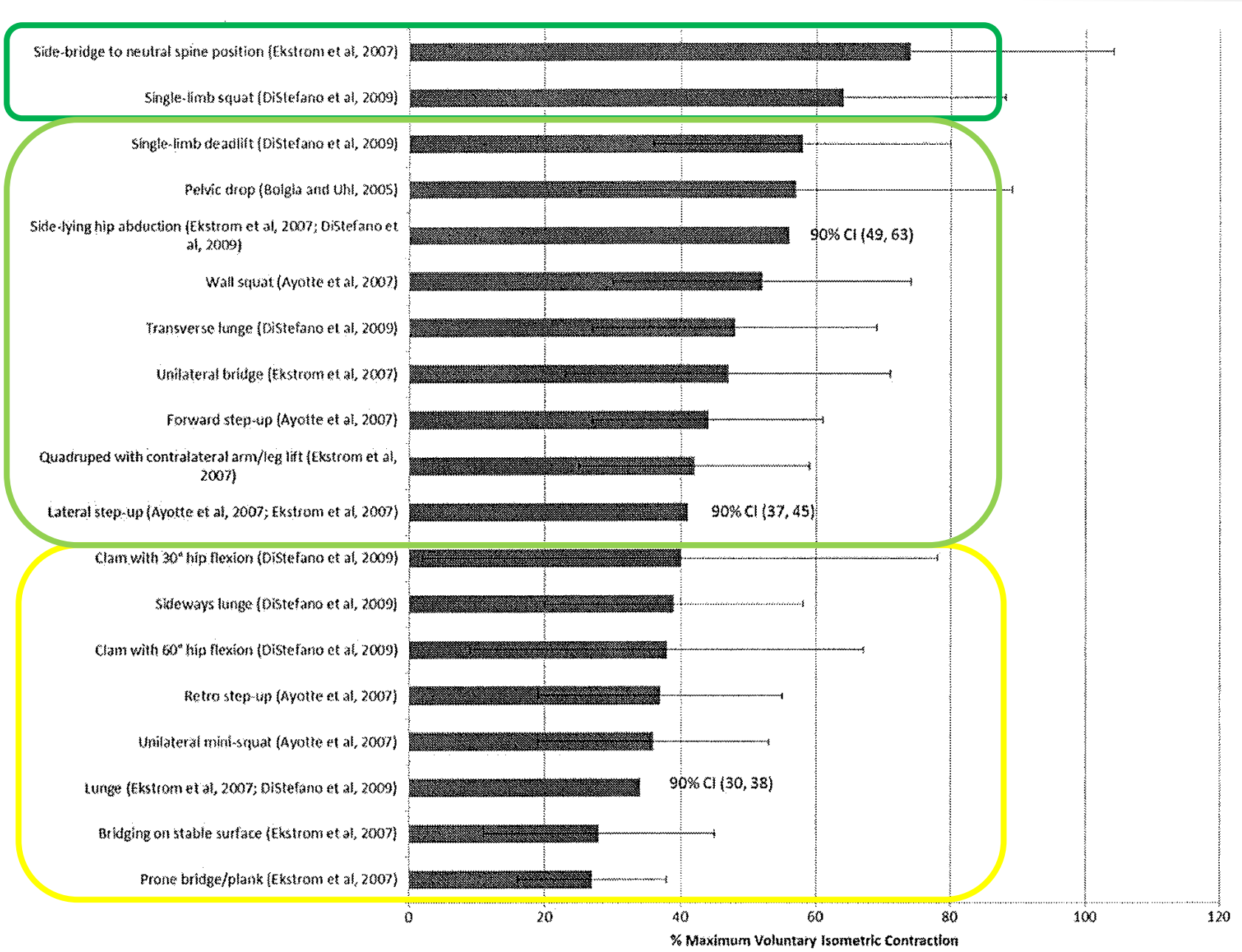
Variable	Frontal SHA-N	Frontal SHA-MR	Frontal SHA-LR
Gluteus medius	34.2 (11.8)[a]	45.3 (20.5)	35.3 (12.5)
Tensor fasciae latae	30.4 (20.0)	32.6 (24.5)	43.4 (16.6)
Gluteus medius:tensor fasciae latae ratio	1.6 (1.1)	2.0 (1.3)	0.9 (0.4)

Abbreviations: SHA-N, SHA with neutral hip; SHA-MR, SHA with hip medial rotation; SHA-LR, SHA with hip lateral rotation.

[a] Percentage of average maximal voluntary isometric contraction.

Lee, J Sport Rehabil, 2013

Studies without using resistance



Reiman, Phys Ther Pract, 2012

FIGURE 2 Gluteus medius percent maximum voluntary isometric contraction ranking of exercises.

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"Very High" Category

Boren, Int J Sports Phys Ther, 2011

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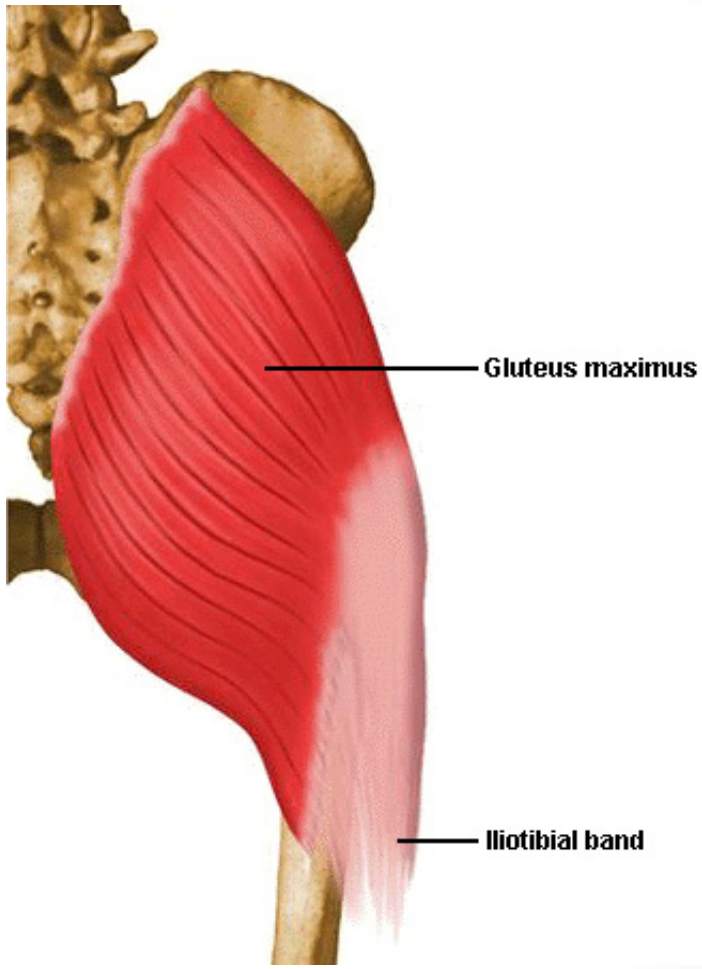
Selkowitz, JOSPT, 2013

LAB SKILLS / YOUR IDEAS

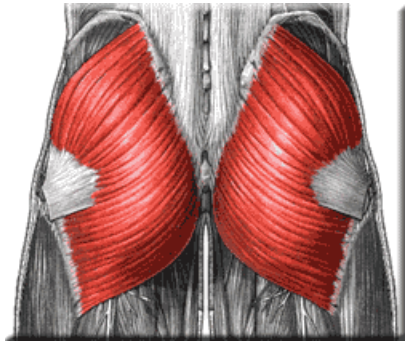
Gluteus Maximus

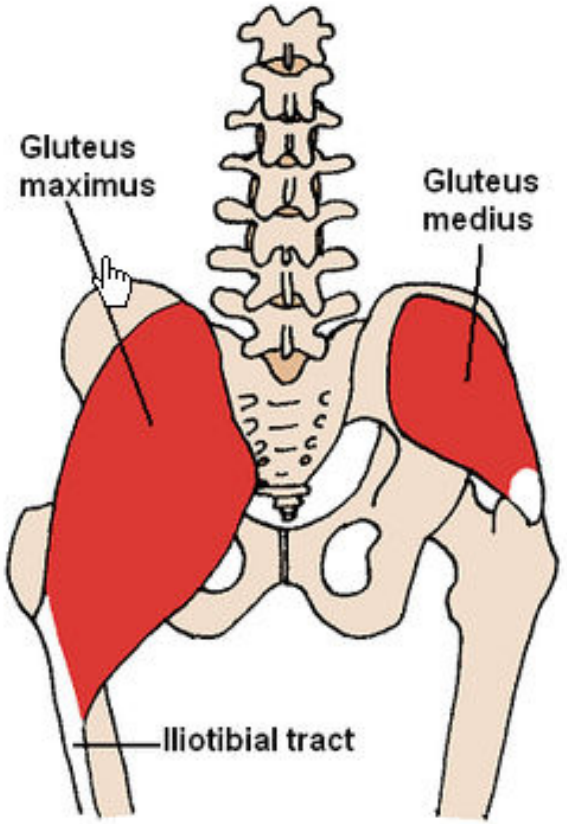
- **Proximal Attachment:** Gluteal line, ilium, sacrum
- **Distal Attachment:** ITB / TFL, gluteal tuberosity
- **Innervation:** Inferior gluteal nerve (L5, S1, S2)
- **Action:** Major extensor of hip joint, assists in externally rotating the thigh; upper and middle third section of the muscle are abductors



Reiman, Phys Theory and Prac, 2012

Anatomy




Gluteus maximus
Gluteus medius
Iliotibial tract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"Gluteus Maximus, you're nothing but a bum."

MMT

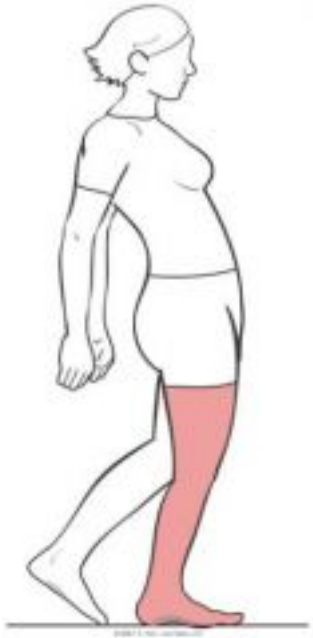
- **Gluteus Maximus:** Bent knee hip extension to isolate the GMAX
- ** Also notice the timing
- Patient may want to fire their hamstring muscles to compensate for a weak GMAX.

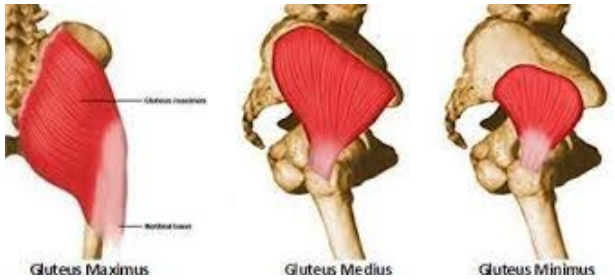
Muscle activation during gait

- The gluteus maximus has a large capacity for external rotation when the hip is at 0° flexion.
- At 0° flexion all of the compartments of gluteus maximus assist in external rotation
- However, as the hip is flexed, the anterior compartments of the gluteus maximus switch from external rotators to internal rotators.

Delp et al, J Biomech, 1999

Gluteus Maximus





- When the GMAX is weak there is an obvious backwards lurching pattern noticed during gait.
- It occurs at heel strike on the weakened side.
- GMAX is needed in midstance to keep upright.

- Compensation during trunk movement
- Center of Gravity stays behind the hip resulting in flexion of hip creating GMAX Lurch

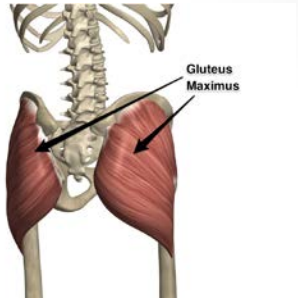
Clinical Pearl

- Compare timing and magnitude of GMED and GMAX activation during running between males and females
  - Healthy runners, 18-35yo
- Surface Electrodes
- GMAX MVIC measured in prone positions on an exam table with 0 degrees hip flex and 90 degrees knee flexion
- No difference in GMAX timing
- Differences in muscle activation levels

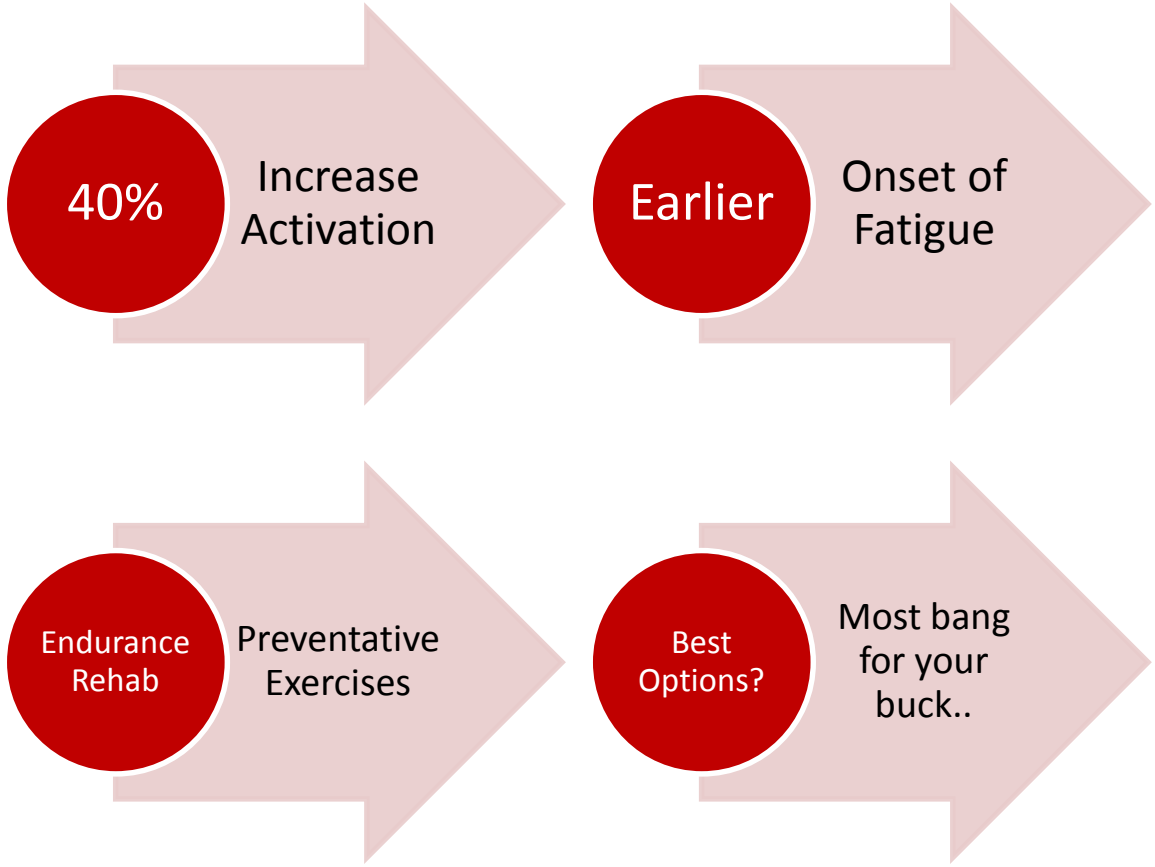
GMAX peak activation level was 40% greater in females compared to males

Wilson, Clin Biomech, 2012

Clinical Pearl



- What does this mean?



Wilson, Clin Biomech, 2012

Which Exercises?

Reminder…….

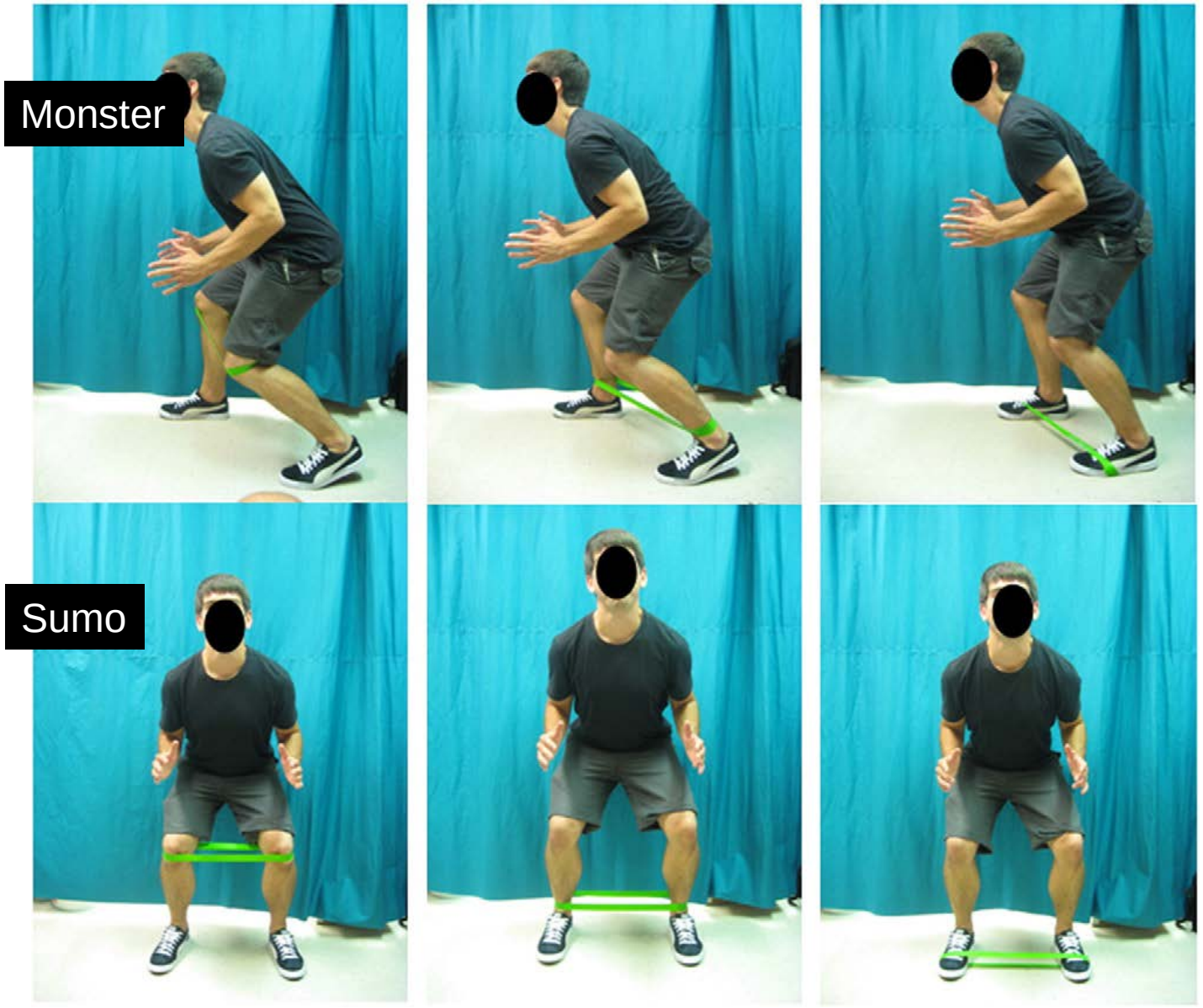
- EMG is typically expressed as a %MVIC (percentage of the maximal voluntary isometric contraction)
  - Low-level muscle activation: 0–20% MVIC
  - Moderate-level activation: 21–40% MVIC
  - High-level activation: 41–60% MVIC
  - Very high-level activation: > 60% MVIC
- Contaminate the desired muscle's EMG signal with that of nearby muscles (i.e., cross-talk)

Escamilla, JOSPT, 2010

Location of Resistance Bands

- Surface EMG
- 9 males
- GMED, GMAX and TFL
- Three resistance band placements during ‘Monster Walks’ and ‘Sumo Walks’
  - Around the knees
  - Around the ankles
  - Around the feet

Cambridge, Clin Biomech, 2012



“Moderate” Category

Cambridge, Clin Biomech, 2012

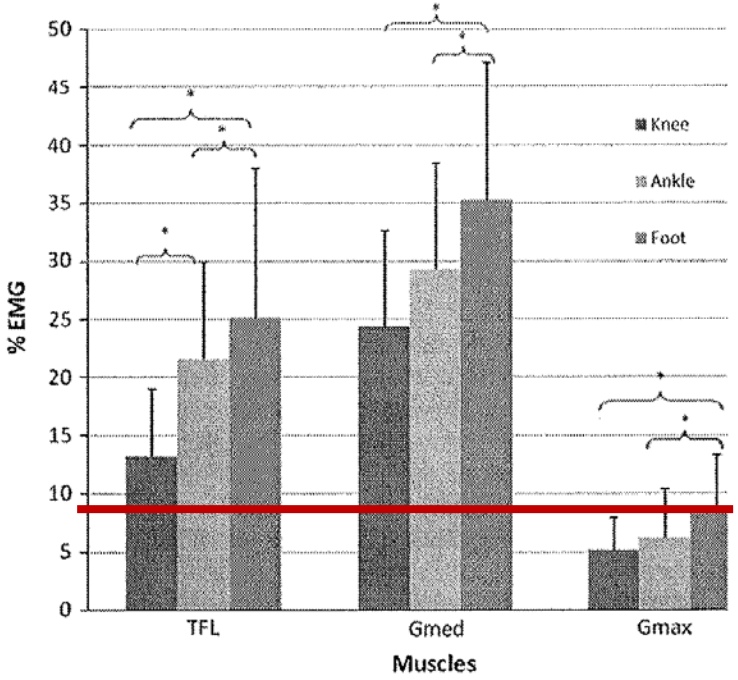


Fig. 4. Mean EMG Sumo walks is shown here with error bars set to the respective SD. A progressive activation is observed in general with the GMed activation. Notice the pattern TFL does not show a significant increase with the foot placement; while the GMax only increases significantly with the foot placement. *Statistical significant difference.

Sumo (frontal)

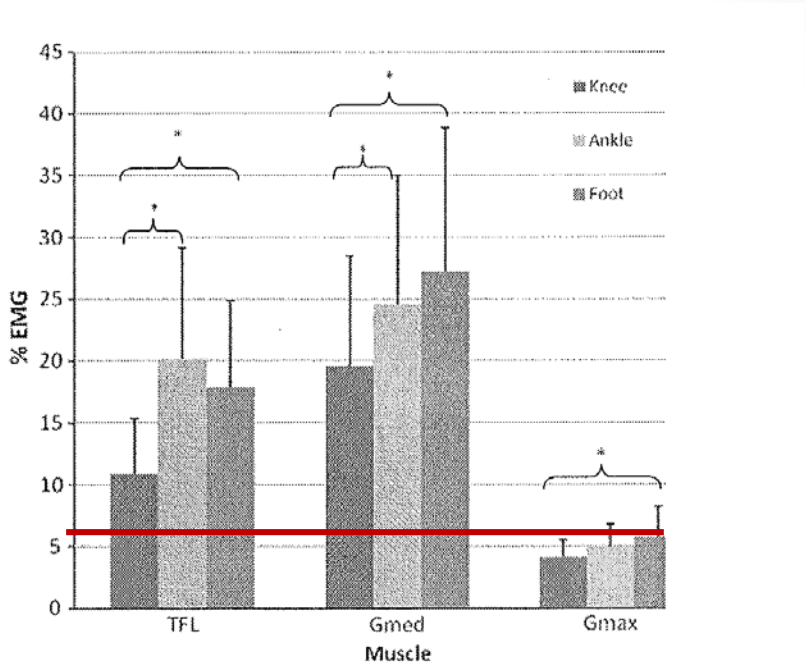


Fig. 5. Mean EMG for the Monster walk exercise is shown here with error bars set to the respective SD. Monster walks demonstrates the progressive nature of the activation patterns. Generally, GMed increases with distal band placement, while TFL is unaffected with the foot placement and GMax only increases with the foot placement. *Statistical significant difference.

Monster (sagittal)

"Moderate" Category

Location of Resistance Bands

- **GMAX** activation progressively increased when moving the band distally

- **THM:**
  - Bands on forefoot didn't increase TFL, preferentially activating gluteal muscles
  - Bands on the forefoot created an external rotation moment, which increased GMAX mean activation significantly
    - 60% Sumo Squat
    - 40% Monster Walks

Cambridge, Clin Biomech, 2012

4-way hip (stance AND moving limb)

- Surface EMG
- 26 active and healthy people
- GMED and GMAX
- 4-way hip motions and stance and moving limb

Youdas, J Sport Rehabil, 2014

Table 2 Comparison of Gluteus Maximus Muscle Activation Levels (% Maximum Voluntary Isometric Contraction [MVIC]) Between the Moving and Stance Limbs During Hip-Joint-Strengthening Exercise Using Elastic-Tubing Resistance, Mean ± SD

Exercise	Moving-limb %MVIC	Stance-limb %MVIC	*P*
Cross-over	12.3 ± 13.2	9.5 ± 6	.341
Reverse cross-over	16.4 ± 10.8	21.9 ± 21.7‡	.285
Front pull	13.4 ± 14.2	17.3 ± 11.3‡	.322
Back pull	39.6 ± 18.2†	12.5 ± 8.2	<.001*

*Gluteus maximus recruitment is greater in the moving limb than stance limb when performing the back-pull exercise.

†For the moving limb, gluteus maximus muscle recruitment is greater for the back-pull exercise than for the cross-over, reverse cross-over, and front-pull exercise ($P < .001$).

‡For the stance limb, gluteus maximus muscle recruitment is greater in the reverse cross-over ($P = .032$) and front-pull ($P = .004$) exercises than the cross-over exercise.

"Moderate" Category

Youdas, J Sport Rehabil, 2014

GMAX activation

- Surface EMG
- 21 healthy, physically active subjects
- GMAX activation during 12 different exercises

DiStefano et al, 2009, JOSPT

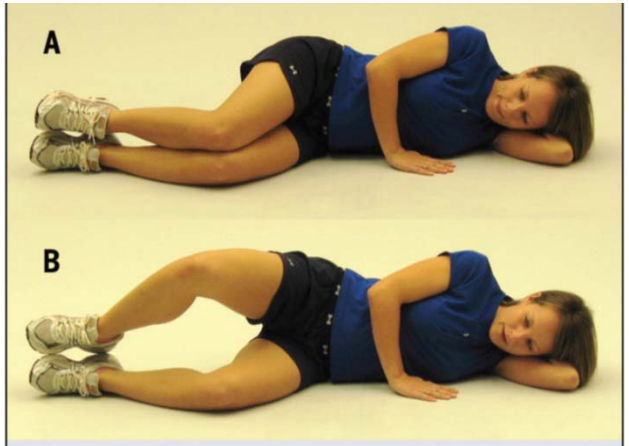


FIGURE 1. Start and end position for hip clam exercise with 60° hip flexion (**FIGURE 1A**); middle position for hip clam exercise with 60° hip flexion (**FIGURE 1B**).

FIGURE 2. Middle position for side-lying hip abduction exercise.

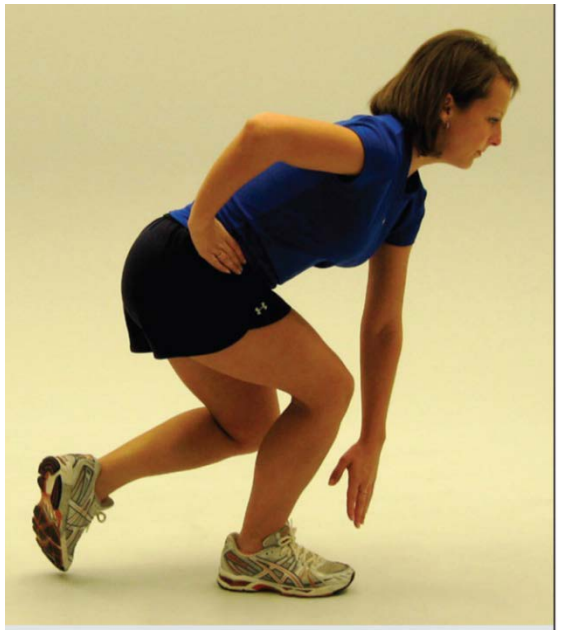


FIGURE 3. Single-limb squat exercise.

FIGURE 4. Single-limb deadlift exercise.

DiStefano et al, 2009, JOSPT

FIGURE 5. Lateral band walks.

FIGURE 6. Forward lunge.

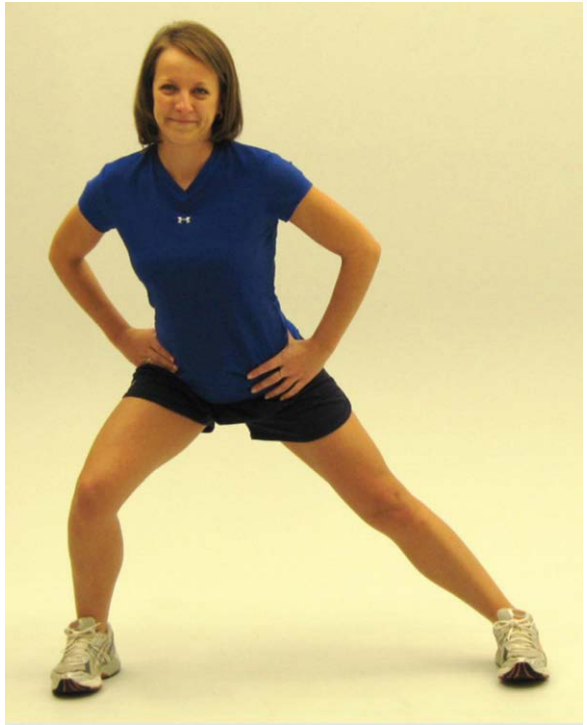


FIGURE 7. Sideways lunge.

DiStefano et al, 2009, JOSPT

FIGURE 8. Transverse lunge.

FIGURE 9. Landing position for multiplanar hop exercises.

DiStefano et al, 2009, JOSPT

TABLE 3

Normalized Gluteus Maximus Mean Signal Amplitude (% MVIC)

Exercise	Mean ± SD (95% CI)
Single-limb squat	59 ± 27 (47, 72)
Single-limb deadlift	59 ± 28 (46, 71)
Transverse lunge	49 ± 20 (39, 58)
Forward lunge	44 ± 23 (33, 54)
Sideways lunge	41 ± 20 (32, 50)
Side-lying hip abduction	39 ± 18 (31, 47)
Sideways hop	30 ± 19 (31, 48)
Clam with 60° hip flexion	39 ± 34 (24, 54)
Transverse hop*†	35 ± 16 (28, 43)
Forward hop*†	35 ± 22 (25, 45)
Clam with 30° hip flexion*†	34 ± 27 (21, 46)
Lateral band walk*†‡	27 ± 16 (20, 35)

Abbreviations: CI, confidence interval; MVIC, maximum voluntary isometric contraction.
* *Exercises are significantly different than the single-limb squat* ($P<.05$).
† *Exercises are significantly different from the single-limb deadlift* ($P<.05$).
‡ *Exercises are significantly different from the transverse lunge* ($P<.05$).

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"High" Category

Journal of Orthopaedic & Sports Physical Therapy
JOSPT

Which exercises?

- Gluteus Maximus
  - SL squat
  - SL deadlift (RDL)
  - Transverse lunge

FIGURE 4. Single-limb deadlift exercise.

FIGURE 3. Single-limb squat exercise.

FIGURE 8. Transverse lunge.

"High" Category

4 step-up variations

- Surface EMG
- 15 healthy females
- GMED, GMAX, biceps femoris(BF), rectus femoris, semitendinosus (ST), vastus lateralis, and vastus medialis(VM)
- 4 step-ups exercises
  - step-up
  - crossover step-up
  - diagonal step-up
  - lateral step-up

Simenz, J Strength Cond Res, 2012

Table 3. RMS EMG data for GMx, expressed as a percentage of MVIC for each 6RM during eccentric and concentric phases of 4 step-up variations ($N = 14$).*

Eccentric phase	Step-up†‡	Diagonal step-up	Crossover step-up	Lateral step-up
	97.47 ± 84.58	82.42 ± 51.42	80.41 ± 55.20	75.54 ± 46.86
Concentric phase	Step-up†‡§	Lateral step-up	Diagonal step-up	Crossover step-up
	240.98 ± 201.56	152.96 ± 133.3	144.00 ± 79.09	127.98 ± 72.07

*RMS = root mean square; EMG = electromyography; GMx = gluteus maximus; RM = repetition maximum; MVIC = maximal voluntary isometric contraction.
†Significantly different from lateral step-up ($p \leq 0.05$).
‡Significantly different from crossover step-up ($p \leq 0.05$).
§Significantly different from diagonal step-up ($p \leq 0.05$).

Step-up Exercise due to GMAX inferior-superior pull.

"Very High" Category

Simenz, J Strength Cond Res, 2012

GMAX Activation

- Surface EMG
- 24 healthy subjects
- GMED and GMAX activation during 18 exercises

Boren, Int J Sports Phys Ther, 2011

Ranked GMAX activation by %MVIC

Table 5. *Results for Gluteus Maximus recruitment, %MVIC and rank for all exercises.*

Exercise condition	# Subjects Included for analysis	%MVIC Gluteus Maximus	Rank Gluteus Maximus
Front plank with Hip Ext	22	106.22	1
Gluteal squeeze	22	80.72	2
Side plank abd, DL up	22	72.87	3
Side plank abd, DL down	21	70.96	4
Single limb squat	22	70.74	5
Skater squat	21	66.18	6
Lateral step-up	20	63.83	7
Quadruped hip ext, DOM	22	59.70	8
Single limb deadlift	21	58.84	9
Forward step-up	22	54.67	10
Single limb bridge, stable	21	54.24	11
Clamshell (Hip Clam) 1	22	53.10	12
Side-lying abd	22	51.13	13
Single limb bridge, unstable	18	49.35	14
Hip circumduction, stable	22	37.85	15
Dynamic leg swing	22	33.65	16
Hip circumduction, unstable	22	28.87	17
Clamshell (Hip Clam) 3	22	26.63	18
Clamshell (Hip Clam) 4	22	26.22	19
Pelvic Drop	22	25.10	20
Quadruped hip ext, non-DOM	22	21.04	21
Clamshell (Hip Clam) 2	22	12.36	22

Table 5.

Results for Gluteus Maximus recruitment, %MVIC and rank for all exercises.

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Single limb squat	22	70.74	5
Skater squat	21	66.18	6
Lateral step-up	20	63.83	7
Quadruped hip ext, DOM	22	59.70	8

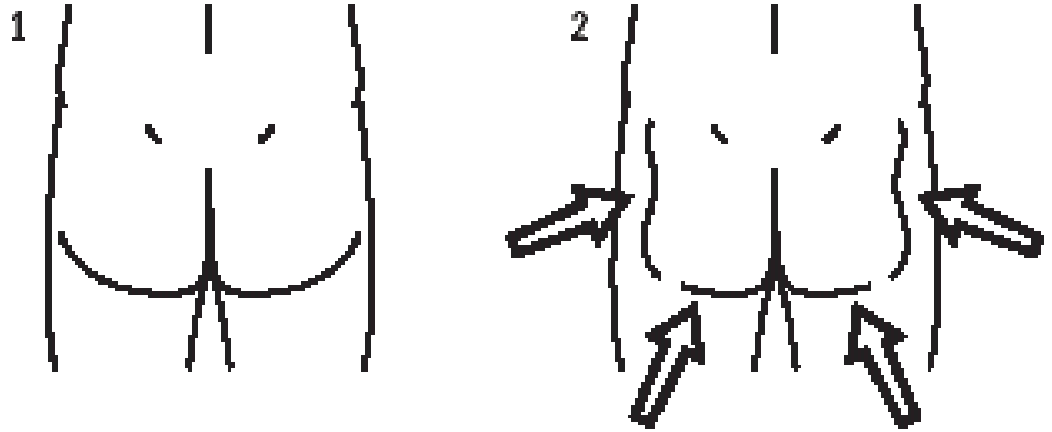
"Very High" Category

Boren, Int J Sports Phys Ther, 2011

Front Plank with Hip Extension: (106.22% MVIC) #1
Prone plank with neutral alignment. Subject lifts the dominant leg off of the ground, flexes the knee of the dominant leg, and extends the hip past neutral hip alignment by bringing the heel toward the ceiling for one beat and then returns to parallel for one beat.

“Very High” Category

Boren, Int J Sports Phys Ther, 2011



Gluteal Squeeze: (80.72% MVIC) #2
In standing with feet shoulder-width apart,
subject squeezes gluteal muscles for two beats and then relaxes for two beats. Subjects were instructed to maximally contract the gluteal musculature during the exercise.

"Very High" Category

Boren, Int J Sports Phys Ther, 2011

Side Plank with Abduction:
dominant leg up (72.87% MVIC) #3
dominant leg down (70.96% MVIC) #4
Start with subject in a side plank position with shoulders, hips, knees, and ankles in line, and then to rise to plank position. The subject is allowed upper extremity support as seen. While balancing on elbows and feet, the subject raises the top leg into abduction for one beat and then lowers leg for one beat.
Subject maintains plank position throughout all repetitions

"Very High" Category

Boren, Int J Sports Phys Ther, 2011

Single Limb Squat (70.74% MVIC) #5
Subject stands on the dominant leg, slowly lowering the buttocks to touch a chair 47cm in height for two beats and then extends back to standing for two beats.

Boren, Int J Sports Phys Ther, 2011

"Very High" Category

Table 5.

Results for Gluteus Maximus recruitment, %MVIC and rank for all exercises.

Exercise condition	# Subjects Included for analysis	%MVIC Gluteus Maximus	Rank Gluteus Maximus
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Skater squat	21	66.18	6
Lateral step-up	20	63.83	7
Quadruped hip ext, DOM	22	59.70	8

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Boren, Int J Sports Phys Ther, 2011

Skater Squat (66.18% MVIC) #6

Subject stands on the dominant leg and performs a squat to a comfortable knee flexion angle for two beats down and two beats up with the non-dominant leg extended at the hip and flexed at the knee. The torso twists during the squat. The toe of the non-dominant leg was permitted to touch the ground between repetitions.

"High" Category

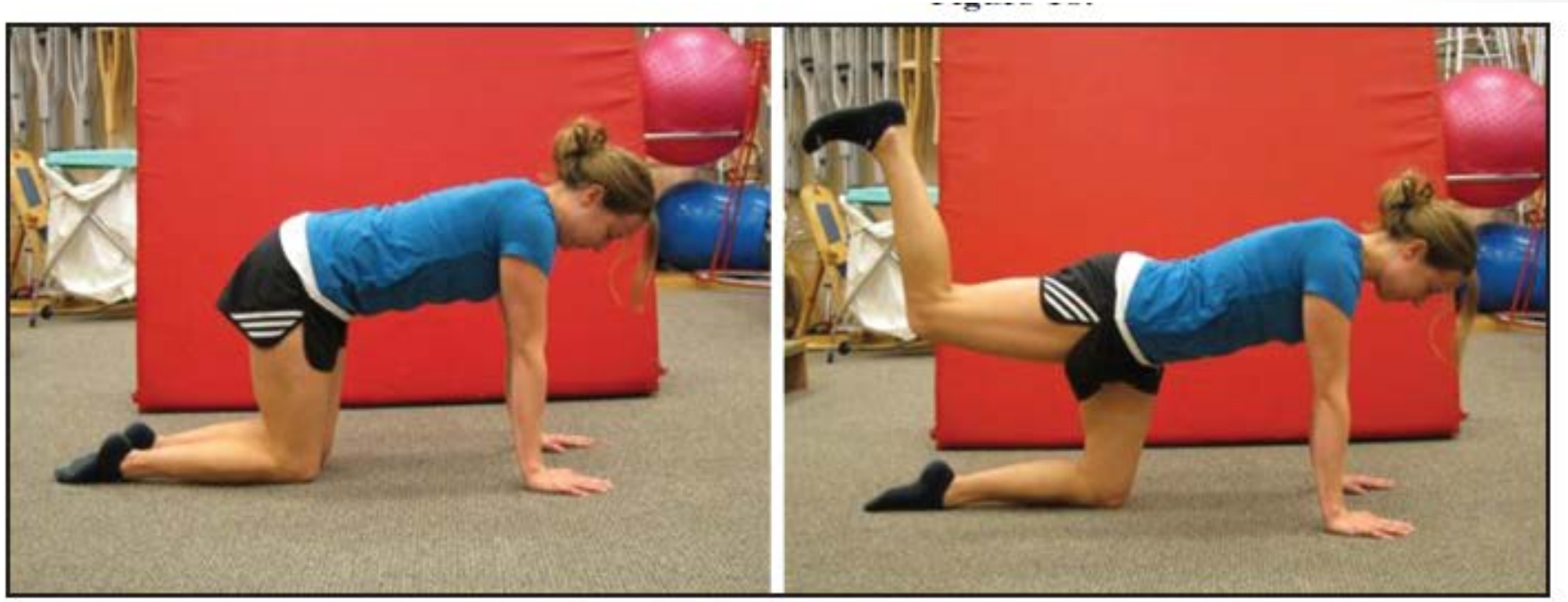
Boren, Int J Sports Phys Ther, 2011

Lateral Step up (63.83% MVIC) #7

Subject stands on the edge of a 15cm box on the dominant leg and squats slowly to lower the heel of the non-dominant leg toward floor for one beat and then returns to start position during the next beat.

"High" Category

Boren, Int J Sports Phys Ther, 2011



Quadriped Hip Extension (59.70 % MVIC) #8

In quadruped the subject extends the dominant leg at the hip, while keeping the knee flexed 90 degrees, to lift the foot toward the ceiling to achieve neutral hip extension for two beats and then returns the dominant leg to the start position for two beats. This exercises was repeated with the non-dominant leg.

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Boren, Int J Sports Phys Ther, 2011

Comparison across previous studies…

Table 8. *Comparison of rank order of exercises for recruitment of gluteus maximus between the current study and Distefano,[3] and Ayotte,[5] using %MVIC.*

	Exercise condition	Current Study	Distefano[3]	Ayotte[5]
1	Front plank with Hip Ext	106		
2	Gluteal squeeze	81		
3	Side plank abd, DL up	73		
4	Side plank abd, DL down	71		
5	Single limb squat	71	59	86*
7	Lateral step-up	64		56
9	Single limb deadlift	59	59	
10	Forward step-up	55		74
12	Clamshell (Hip Clam) 1	53	34	
13	Side-lying abd	51	39	

*Single-limb squat

GMAX Activation continued…

- Determine which modified positions of the SL bridge is best for GMAX activation
- 28 healthy subjects
- 5 SL bridge positions

Lehecka et al, Int J of Sprts Phys Ther, 2017

Best Position

Table 3. *EMG Activity of Hip Muscles in Different Single-Leg Bridge Positions (Mean ± SD of %MVIC)*

	Gluteus Maximus	Gluteus Medius	Biceps Femoris	Dominant Rectus Femoris	Non-Dominant Rectus Femoris	Position Description
Position A	51.02 ± 28.12	57.81 ± 20.72	75.34 ± 24.25	5.83 ± 3.91	20.49 ± 13.04	Dominant leg: 90° knee flexion with foot flat; Non-dominant leg: knee extended and hip neutral
Position B	47.35 ± 27.47	57.23 ± 27.82	23.49 ± 9.30*	8.44 ± 6.25*	19.21 ± 10.07	Dominant leg: 135° knee flexion with foot flat; Non-dominant leg: knee extended and hip neutral
Position C	47.16 ± 28.07	55.05 ± 20.71	69.18 ± 18.49	5.11 ± 3.38*	7.00 ± 5.64*	Dominant leg: 90° knee flexion with foot flat; Non-dominant leg: knee relaxed in flexion with the femur vertical
Position D	49.12 ± 26.37	54.27 ± 20.01	58.71 ± 19.72*	5.22 ± 3.62*	7.67 ± 6.43*	Dominant leg: 90° knee flexion with dorsiflexed ankle; Non-dominant leg: knee relaxed in flexion with the femur vertical
Position E	40.38 ± 24.55*	41.63 ± 18.19*	20.84 ± 12.81*	12.05 ± 9.38*	7.25 ± 6.51*	Dominant leg: 135° knee flexion with dorsiflexed ankle; Non-dominant leg: knee relaxed in flexion with the femur vertical

* indicates a statistically significant change from position A, the traditional single-leg bridge

"High" Category

Lehecka et al, Int J of Sprts Phys Ther, 2017

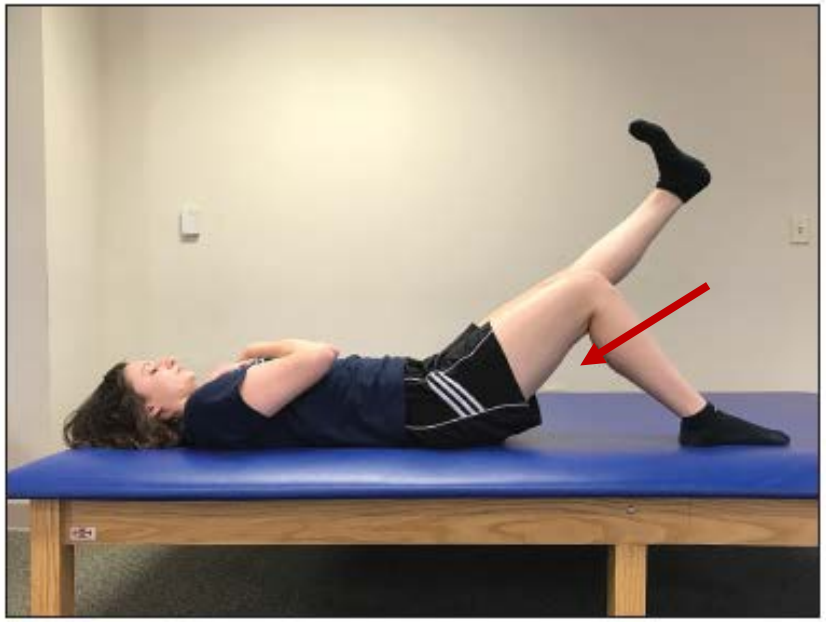

Figure 1. *Position A. Subjects started with their dominant knee flexed to 90° and foot flat. The contralateral knee was extended and its hip remained in neutral. Arms were folded across the chest.*

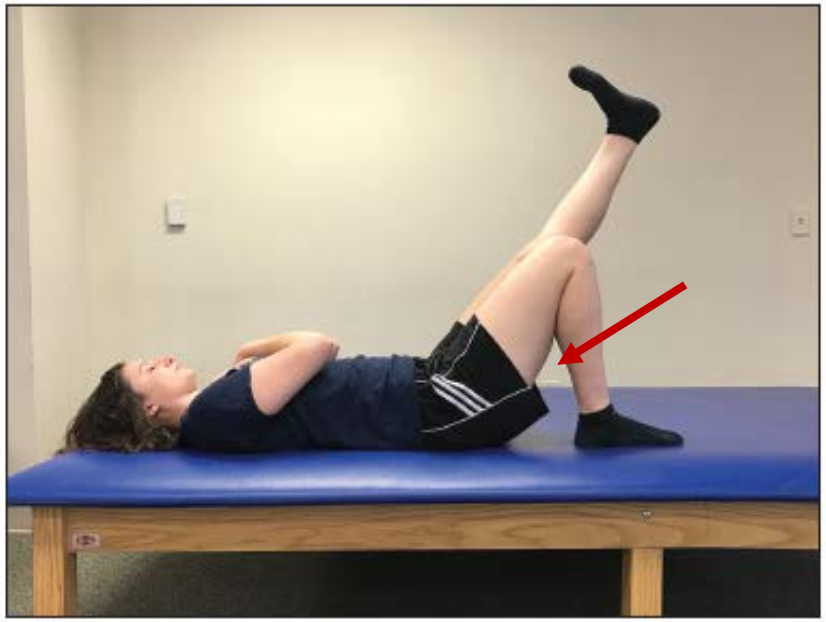

Figure 2. *Position B. Subjects started with their dominant knee flexed to 135° and foot flat. The contralateral knee was extended and its hip remained in neutral. Arms were folded across the chest.*

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Lehecka et al, Int J of Sprts Phys Ther, 2017

Combining Thoughts

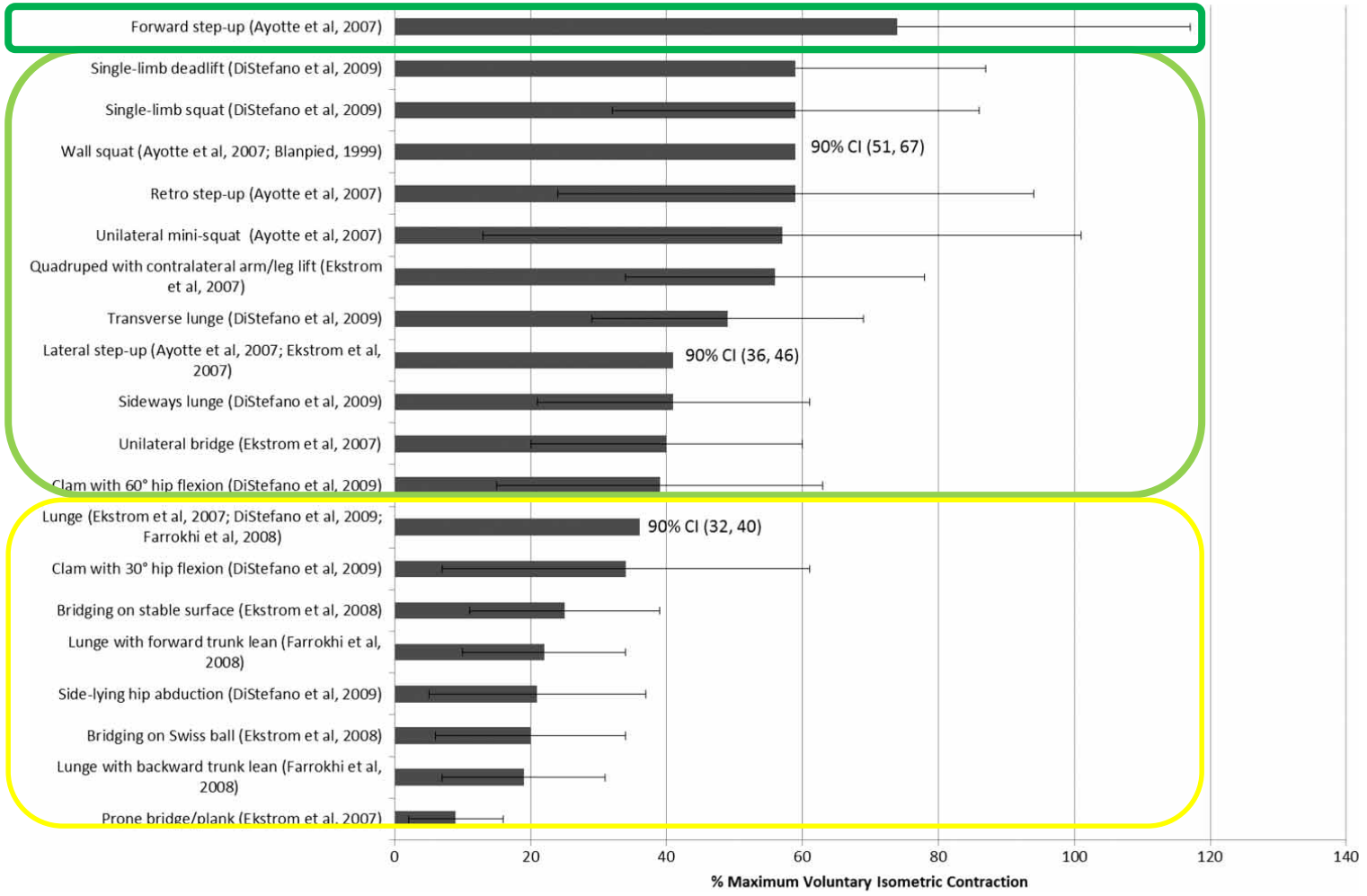

FIGURE 1 Gluteus maximus percent maximum voluntary isometric contraction ranking of exercises.

Reiman, Phys Ther Pract, 2012

TABLE 3

Normalized Gluteus Maximus Mean Signal Amplitude (% MVIC)

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"Very High" Category

Boren, Int J Sports Phys Ther, 2011

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"High" Category

Boren, Int J Sports Phys Ther, 2011

LAB SKILLS / YOUR IDEAS

Thank you!

https://www.foxvalleywebdesign.com/photo-gallery/madison-wi-2015-fvwd-2/