# Hip Position during Common Lower Limb Rehabilitation Exercises Effects Gluteal Electromyographic Activity: A Systematic Review

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## Abstract

Objective: Decreased strength of the hip muscles, especially the Gluteus Maximus and the Gluteal Medius muscles contributes to the etiology of various orthopedic pathologies of the lower limbs, low back pain and pelvic stability. Several studies have evaluated the effect of different proximal rehabilitation exercises by gluteal EMG and the effective position to recruit and activate gluteal musculatures. The systematic review synthesizes the differences in the EMG activation during different hip positions in order to better understand the role of specific hip position in recruiting and activating hip muscle.

Methods: PubMed, EMBASE and WEB OF SCIENCE databases are the main evidence sources searched; searched from 1989 up to April 2015. Search was for the key terms: Electromyography AND hip abduction OR hip extension, EMG activity AND Hip strengthening exercises. Unpublished articles were not sought. After excluding two articles of Case report-based studies, title and abstracts were reviewed. 189 articles were excluded from the title, six articles were excluded because of duplications, eight articles were excluded after reviewing the abstracts and two articles were excluded after reviewing the full text, to end up with 10 relevant and related articles to the review question. Data on research design, participants, EMG variables, hip position and confidence interval were evaluated. Two independent reviewers assessed each paper for inclusion and quality.

Results: Ten prospective observational studies, and no case-control were identified. Five studies had level two evidence which indicated G.Med. EMG Peak magnitude was effectively recruited in NWB hip abduction exercises with resistance. In addition, level three evidence studies show no differences in G.Med level of activation when controlling the external resistance, whereas G.Max, EMG shows effective recruitment during NWB hip extension positioned exercises.

Limitation: Most studies were not sufficiently powered with unreported power of the sample size; only three out of the ten eligible studies reported the power 0.90 - 0.91, as well as lack of control and blindness.

Conclusions: Several previous conducted studies show the association between hip muscles activity and lower limb pathology by evaluating the EMG. The current review aims to evaluate the differences in electromyographic activation with different hip position activities. There was limited evidence due to an absence of control, low sample size and heterogeneity in methodological design. Further research evaluating the value of different hip positions and to rank the best hip position in activating and targeting hip musculature is needed.

Key words: Electromyography activities, Hip abduction, Hip extension, proximal rehabilitation.

## Introduction

Electromyography (EMG) is the electrical voltage associated with muscular contraction. EMG analysis can provide information about timing and intensity of muscle contraction, whether the muscle contracting is in the correct order (phasic) and at the right time. Surface EMG has high Reliability established in ISOMETRIC exercise, but a limited use in dynamic motion (19,20). The improvement in the efficiency of a movement will lead to correct use of muscles (efforts and economics) which will prevent injury.

Decreased strength of the hip muscles (Gluteal muscles) especially the Gluteus Maximus and the Gluteal Medius muscles contributes to the etiology of various orthopedic pathologies of the lower limbs like the patellofemoral pain which accounts for 25%-40% of all knee problems seen in sports and injury clinic(18) and femoroacetabular impingement with an incidence of 25% in men and 5 % in women (asymptomatic young adults) (4), low back pain and pelvic stability (1,2 ). Previous observational research conducted by Tadanobbu et al. found that the delay in these muscles' activity pattern causes sacroiliac instability and increased strain on the soft tissues. N.C Casartelli and N. Maffiuletti found that patients with symptomatic Femoroacetabular impingement (FAI) present with weakness in all hip muscles groups, except for internal rotations and extensors (4). Tadanobou et al. studied the influence of hip joint position on hip muscles' activity and they found that the Gluteal Maximus is significant in early onset recorded by surface Electromyography (s EMG) in two main positions (hip Abduction and Abduction with external rotation) (2). Also in other research conducted by Joseph Mcbeth et al. showed that the Gluteal Medius is most active during hip abduction exercises compared to other positioned exercises by using Electromyography (EMG) (5). Another research study by Kristen Boren ranked the clinical hip exercises in order from highest (EMG) value, to determine which exercises recruit the gluteal muscles, specifically the Gluteal Maximus and Gluteal Mediuse and found that side plank with hip abduction produces the highest value with Maximum Voluntary Isometric Contraction (MVIC) more than 80 % (3). A recent systematic review identified four studies that assessed gluteus maximus and gluteus medius during twenty rehabilitation exercises and categorized them according to the EMG activation level (Reiman et al. 2012) (17).

In a research study by Adam Semciw et al 2014, comparing the surface EMG and fine wire EMG in recording the Gluteus Medius activities during selected Maximum Isometric Voluntary Contraction of the hip they found additional myoelectric activity from middle Gluteus Medius at low intensity by surface EMG (6). Whereas according to the fine wire recordings, Gluteus Medius (GMed) is active at very high intensities during maximum resisted abduction and internal rotation, and active at a very low intensity during maximum resisted external rotation, which means that caution should be used when interpreting surface electrodes study.

Previous conducted studies evaluated the different common lower limb rehabilitation exercises by measuring different EMG variables and no recent systematic review measured the effect of different hip position in EMG activities. The purpose of this systematic review is to know if specific hip exercise positions, especially hip abduction and external rotation, leads to increase the level of Gluteal muscles activation in EMG which indicates improvement in hip muscles' (Gluteal muscles) functioning. The aim of this review is to establish if differing hip positions result in different EMG activity in the gluteal muscles both within asymptomatic and symptomatic populations, which will assess in focusing on variables that should be considered in screening and rehabilitation programs.

## Objectives

With reference to PICOS (Participants, interventions, Comparisons, Outcome and Study design)

| | |
|---|---|
| P | Healthy, Lower Limbs pathology, Athletic sample, patients with lower back pain |
| I | EMG |
| C | None |
| O | Increase in hip muscles activation with different hip positions |
| S | Cohort studies, Cross sectional and Prospective Observational studies |

## Methods

**Eligibility criteria:**

Inclusion criteria:
- Studies investigating hip muscles activity by Electromyography in different hip positions with and without rehabilitation exercises.
- Cohort studies, Cross sectional studies and observational studies.
- Limited to English language.
- Limited to humans.
- Studies from 1989 – 2015

Exclusion criteria:
- Case reports and Case series.

**Search strategy:**
PubMed, EMBASE and WEB OF SCIENCE databases are the main evidence sources searched, searching from 1989 up to April 2015. Search for the key terms Electromyography AND hip abduction OR hip extension. EMG activity AND Hip strengthening exercises. Unpublished articles were not sought, although this may lead to publication bias.

**Review process:**
Title and Abstracts of the identified articles in the search, reviewed and any duplications deleted. All publications were assessed by two independent reviewers for inclusion with the full texts of the obtained published articles. Any discrepancies were resolved during a consensus meeting and a third reviewer was available if needed.

**Study analysis:**
One scale was used to evaluate methodological quality, MINORS checklist (Methodological Index For Non-Randomized Studies) (7). MINORS contained 12 items, the first eight being specifically for non-randomized studies. MINORS checklist has external validity and high test –retest reliability. Each item scored as 0 (not reported), 1 (reported but inadequate), or 2 (reported and adequate). The ideal global score was 16 for non-comparative studies and 24 for comparative studies (7). MINORS score varies from low score 6 to high score 18(8). Sample size, participants' demographics, population sources, activities and EMG variables were extracted and evaluated, shown in Tables 1, 2.

**Quality assessment:**
Preferred Reporting Items For Systematic Reviews and Meta-analysis (PRISMA) 2009 checklist (10) was followed to structure the review and the Methodological Index For Non-Randomized Studies (MINORS) (7) checklist used to assess the quality of the included searched articles. MINORS contained 12 items, the first eight being specifically for non-randomized studies. MINORS checklist has external validity and high test –retest reliability. Each item was scored as 0 (not reported), 1 (reported but inadequate), or 2 (reported and adequate). The global ideal score was 16 for non-comparative studies and 24 for comparative studies. MINORS score varies from low score 6 to high score 18 (8). Level of evidence was evaluated using Oxford Center of Evidence Based Medicine recommendation. Table 3 A and B:

**Table 3 A:**

| Methodological Index For Non-Randomized Studies (MINORS) | |
|---|---|
| The items are scored | Meaning of the score |
| 0 | Not reported |
| 1 | reported but inadequate |
| 2 | reported and adequate |

**Table 3B**

| CEBM of Oxford – Level of evidence (March 2009) | |
|---|---|
| Level of evidence | Characteristic of the study |
| 1a | SR (homogeneity) of RTC |
| 1b | Individual RCT (with marrow confidence interval) |
| 1c | All or non |
| 2a | SR (homogeneity) of cohort studies |
| 2b | Individual cohort study or low quality RCT <80% follow up |
| 2c | Outcome research, ecological studies |
| 3a | SR (homogeneity) of case –control |
| 3b | Individual case control study |
| 4 | case series and (poor quality cohort and case control) |
| 5 | Expert opinion |

## Results

Search results details and process of inclusion and exclusion of the searched published articles is explained in Figure 1. After excluding two articles of Case report-based studies, title and abstracts were reviewed . 189 articles excluded from the title, six articles were excluded because of the duplications, eight articles were excluded after reviewing the abstracts and two articles were excluded after reviewing the full text to end up with 10 relevant and related articles to the review question; all 10 studies evaluated the GMed and GMax, while three studies evaluated hamstring, quadriceps muscles. The reason for excluding the two articles after reviewing the full text is the hip positions during the activity were evaluated in the studies. There is currently low MINORS score [ 10,13 ]; two contained evidence that gluteal muscles (GMed) peak magnitude were effectively recruited in NWB (hip abduction) exercise with resistance and the second lot of evidence indicated no differences between elastic resistance or machine resistance in peak magnitude during the hip abduction, external rotation and internal rotation position, whereas the other article with MINORS score 11 showed no differences in the GMed muscles activation between NWB and WB when controlling the external peak resistance. The same study shows effective recruitment of GMax in NWB with hip extension. In addition, another study with strong evidence indicates that (Maximum abduction strength unit) does not change with increasing hip flexion angle. A study by Kristen Boren et al with low MINORS score of 10 confirms that EMG magnitude (%MVIC) higher level is achieved during side-lying hip abduction in GMed. and during single limb squat in GMax. However, the remaining studies with low-moderate score assess the onset timing of the EMG increase in abduction and external rotation, whereas one study shows 2 SD increase in EMG activity from natural sit-to-stand in older adults of GMed.

**Figure 1: Flow diagram summarizing study selection for inclusion**

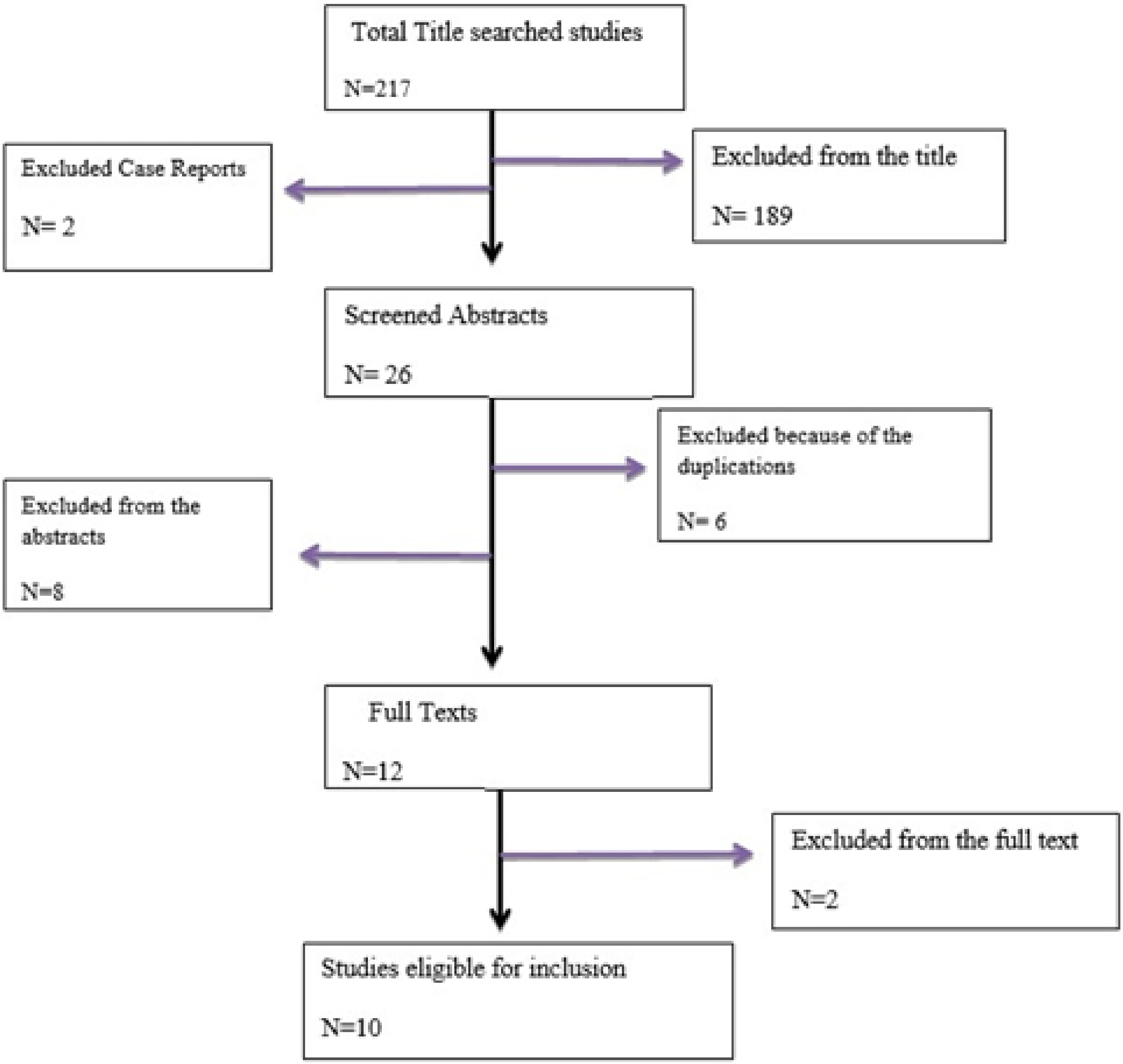

**Table 1: Study details including sample size and participants demographic**

| Paper | Sample Size | Age range(mean) | Gender |
|---|---|---|---|
| Cale A. Jacobs et al. | 15 volunteers | 57.4+- 10.2 | 6(F), 9(M) |
| Matthew J. Mac Askill et. al | 34 | 21.2+-1.8 (M)<br>21.7+-1.6 (F) | 20(F)<br>14(M) |
| Adam I. Semciw. et al | 10 volunteers | 23.8(1.6) years | 4 (F)<br>6(M) |
| Ji-hyun Lee et al | 19 | 21.00 +- 1.73 | 11(F)<br>8(M) |
| Hiroyuki Fujisawa et al | 27 | 21.5+-1.2 | 27 (M) |
| Donald A Neumann et al | 40 | 26.5+-506 | 20(F)<br>20(M) |
| Tadanobu Suehiro et al | 21 | 20.2+-0.4 | 21 (M) |
| Mikkel Brandt et al | 16 | 45.7+- 8.6 | 16 (F) |
| Eun-Mi Jang et al | 30 | 27.13+- 5.26 (young)<br>67.75 +- 1.61 (elderly) | 30 (F) |
| Kristen Boren et al | 24 | 21-23 year (mean: NR) | NR |

**Table 2: Population sources, activities, evaluated muscles and EMG variables.**

**A- Symptomatic Populations:**

| Paper | Population Sources | Activities | Evaluated Muscles (Method) | EMG Variable | Conclusion P value |
|---|---|---|---|---|---|
| Cale A. Jacobs et al. | Post-unilateral primary total hip arthroplasty | Weight bearing and Non weight bearing exercises | Gluteus Medius (surface) | Root-Mean-Square amplitude (%MVIC) | No differences noted between WB and NWB exercises in activating GMed P<0.05 |
| Ji-hyun Lee. et al | Not reported | Different hip rotation during isometric side-lying hip abduction | Gluteus Medius, Gluteus Maximus, Tensor fasciae latae (surface) | Peak magnitude (%MVIC) | GMed EMG activity significantly increased with hip abduction and medial rotation. P< .017 |

**B- Asymptomatic Populations:**

| Paper | Population Sources | Activities | Evaluated Muscles (Method) | EMG Variable | Conclusion P value |
|---|---|---|---|---|---|
| Matthew J. MacAskill. et .al | Subjects respond to fliers, electronic advertisement and word of mouth. | Weight bearing and Non weight bearing exercises. | Gluteus Medius Gluteus Maximus (surface) | Peak magnitude (%MVIC) | Gmax: effectively recruited in NWB exercise with hip extension. Gmed: effectively recruited in NWB exercise with resistance abduction. P0.55 |
| Adam I. Semciw. et al | Not reported | Maximum isometric voluntary contraction (abduction, internal rotation, external rotation) | Gluteus Medius, Gluteus Maximus. (surface, intramuscular) | Average magnitude of activity (normalized amplitude, %MVIC) | Additional activity from middle Gmed during low intensity and under high load. $P<0.05$ |
| Hiroyuki Fujisawa et al | Not reported | Incremental increase in hip flexion angle during isometric hip abduction. | Gluteus Maximus (upper and lower portion) Gluteus Medius Tensor fasciae latae. (surface) | Maximum abduction strength, unit (%MVIC) | Gmed EMG activity during isometric abduction does not change with increase in hip flexion angle. $P<0.001$ |
| Donald A Neumann. et al | College students | Hip abduction | Hip abductors(surface) | Neural drive index (NDI) (magnitude of submaximal% isometric hip abduction) | Rapid increase of the NDI as the length of the muscle shortened $P< 0.05$. |
| Tadanobu Suehiro. et. al | Not reported | Neutral Abduction, Abduction and external rotation. | Gluteus Maximus, Hamstring, Lumbar erector spinae, Lumber Multifidus (surface) | Onset timing (GM) increase in EMG activity during ABER in compare to N. | Gmax EMG activity onset timing earlier relative to the hamstring during hip abduction. $P<0.05$ |
| Mikkel Brandt. et. al | Office workers and laboratory technicians. | Hip abduction (elastic resistance / machine) Hip adduction (elastic resistance /machine) | Gluteus Medius, Gluteus Maximus, Vastis medialis, Vastus lateralis, rectus femoris, external oblique, rectus abdominas. (surface) | Peak magnitude (% Maximal normalised EMG) | Elastic resistance hip abduction associated with greater muscular recruitment measured by EMG in compared to the Machine exercise abduction. $P<0.05$ |

**B- Asymptomatic Populations: (continued)**

| | | | | | |
|---|---|---|---|---|---|
| Eun-Mi Jang et al | University and community. | Natural sit-to-stand Sit-to-stand with abduction. | Gluteus Medius Rectus femoris | -Onset timing (2 SD increase in EMG activity from natural sit-to-stand in older adult) of GMed. -Onset timing of rectus femoris (4 SD decrease in EMG activity during sit-to-stand with abduction) | Gmed EMG activity in the elderly significantly increased during natural STS compared to young female subjects. P<0.05 |
| Kristen Boren. et al | University, community | 18 hip strengthening exercises. | Gluteus Medius, Gluteus Maximus | Peak magnitude (%MVIC) | Gmed: Higher %MVIC achieved during side-lying hip abduction. Gmax: Higher %MVIC during single limb squat P value (not reported). |

## Discussion

This systematic review was completed by synthesis findings from previous research evaluating the associations of different hip exercises and activities in various hip positions with the level of EMG muscle activations. Oxford Centre for evidence-based medicine –levels of evidence (March 2009) was used to assess the level of the evaluated studies' evidence (9). All the ten evaluated studies were graded as level two (2c) evidence, which evaluates different EMG variables:

- **EMG Peak Magnitude:**

Two studies among symptomatic (weak GMed.) and asymptomatic population evaluated EMG peak magnitude and indicated that the GMed. Muscle EMG peak magnitude significantly increased with hip abduction and medial rotation position and side-lying hip abduction exercise, while the GMax. higher peak magnitude was achieved with single-limb squat exercise.

- **EMG Level of activation:**

Six studies evaluated the EMG level of activation; three out of the six studies measured the EMG level of activation and the onset of timing among hip muscles which significantly increased during hip abduction position and activities. The remaining three studies evaluated muscle activation level (peak or average magnitude) of the gluteal muscles during different hip positions and they found that the activation level increased in specific hip positions (abduction and extension).

- **EMG Maximum abduction strength unit:**

One study indicated GMed EMG maximum abduction strength unit does not change with increasing hip flexion angle.

- **EMG Onset of timing:**

Only one study measured the EMG timing onset which showed that it increases by 2 SD during natural sit-to-stand among old adults in compression; the EMG timing onset increased by 6 SD during sit-to-stand with abduction activities among young females.

**Limitations:**

- Low sample size.
- Source of the population not reported in four studies out of the ten eligible studies.
- Lack of controls.
- No follow up period.
- P value not reported in one study.

## Conclusion

Current research evaluated the differences in electromyographic activation with different hip position activities and exercises among healthy and individuals with lower limb pathology. Limited evidence was due to an absence of controls, low sample size and heterogeneity in methodological design. All the ten studies had level two evidence, indicating that the GMed. Muscle EMG peak magnitude significantly increased with hip abduction and medial rotation position and side-lying hip abduction exercise. While the GMax. higher peak magnitude was achieved with single-limb squat exercise, while the onset of timing among hip muscles significantly increased during hip abduction position and activities. Six studies evaluated muscle activation level (peak or average magnitude) of the gluteal muscles during different hip positions and they found that the activation level increased in specific hip positions (abduction and extension). One study indicated GMed EMG maximum abduction strength unit does not change with increasing hip flexion angle. Additionally, a study measured the EMG timing onset and shows that it increases by 2 SD during natural sit-to-stand among old adults in compression and the EMG timing onset increases by 6 SD during sit-to-stand with abduction activities among young females. Further research evaluating the value of different hip positions and to rank the best hip position in activating and targeting hip musculature is needed.

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