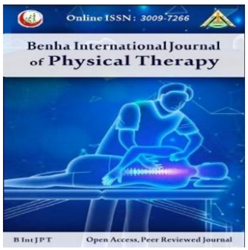
# Benha International Journal of Physical Therapy

**Online ISSN:** 3009-7266 **Home page:** https://bijpt.journals.ekb.eg/


Original research

## Effect of Different Positions on Gluteus Maximus Electrical Activity in Asymptomatic Subjects: A Cross-Sectional Observational Study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**Article history:**
Submitted: 28-09-2025
Revised: 15-10-2025
Accepted: 05-11-2025



**Abstract**

**Background:** The gluteus maximus (GMax) is the largest and most strong muscle in the gluteal area, crucial for strength, movement, and usefulness. Clinicians have emphasized the significance of hip strength in the rehabilitation. Electromyography (EMG) is a method for assessing the electric potential field produced by the depolarization of the sarcolemma. Research indicates that the activation of the gluteus maximus muscle is contingent upon the workout type and the extent of hip extension engaged. **Purposes:** to compare between the effect of 3 different positions (prone, half prone, getting up from squatting positions) on gluteus maximus electrical activity. **Methods**: forty-five healthy volunteers of both gender with age 18- 45 years, were participated in this study, the gluteus maximus electrical activity of every participant were measured by (EMG) from 3 different positions prone lying (straight leg raising) position, half prone position (hip flexion 90°), getting up from squatting position (90° knee flexion). **Results:** The results revealed a statistical significant increase in root mean square (RMS) of gluteus maximums activity from prone lying position compared to half prone positions with p-value=0.001, there was a statistical significant increase in RMS gluteus maximums from prone lying compared to getting up from squatting positions with p-value=0.01 and there was no statistically significant difference between RMS of gluteus maximums from half prone and getting up from squatting positions with p-value=0.98. **Conclusion:** It was concluded that the prone lying (straight leg raising) position was the significant position for increasing gluteus maximus electrical activity.



**Keywords:** Electromyography, Gluteus maximus muscle, Prone lying (straight leg raising) position.


## INTRODUCTION:

The human body functions as a linked mechanical system, with the gluteus maximus contributing to optimal movement and athletic performance through coordinated action with surrounding muscles. Dysfunction in this muscle though often compensated for by the neuromuscular system can lead to altered kinematics and increase the risk of chronic biomechanical overload injuries [1]. Hip extension produced by gluteus maximus muscle is essential for everyday activities and athletic performance. Exercises necessitating hip extension, particularly under load or during explosive actions such as jumping, running, and directional changes, impose considerable demands on the gluteal musculature [2]. The principal muscles involved in hip extension include the gluteus maximus, the long head of the biceps femoris, semimembranosus, semitendinosus, and the hamstring (ischiocondylar) segment of the adductor magnus [3]. The gluteus maximus is recognized as the principal muscle responsible for hip extension during heavy workouts that inadequately engage the hamstrings in activities requiring concurrent hip and knee extension, such as the squat and leg push [4].

Recent systematic reviews confirmed that back squat particularly those performed through full or to a depth where the thighs are parallel to the ground and leg press exercises effectively stimulate gluteus maximus hypertrophy, underscoring its role as the primary hip extensor during loaded movements [4]. Weakness or reduced activation of the gluteus maximus has been consistently linked to chronic low back pain and lower limb injuries. These dysfunctions often result in compensatory overuse of synergist muscles such as hamstrings, quadriceps and lumber extensors leading to biomechanical imbalances and increased injury risk [5,6].

Although loaded resistance exercises such as hip thrusts, deadlifts, step-ups, and squats elicit greater gluteus maximus activation than bodyweight movements [7], bodyweight hip extension exercises remain a common starting point in rehabilitation and athletic training. The orientation of the body relative to gravity particularly the direction of the force vector significantly influences gluteal engagement and functional adaptation [1,8]. Classifying these exercises by force-vector orientation (horizontal vs. vertical) may enhance movement specificity, intermuscular coordination, and transfer to athletic performance [9].

Electromyography (EMG) is a non-invasive technique used to quantify the electrical activity of muscles during contraction and relaxation. Surface EMG (sEMG), in particular, records signals via electrodes placed on the skin above the target muscle, providing insights into motor unit recruitment and coordination. These signals are typically normalized using the percentage of maximum voluntary isometric contraction (%MVIC), allowing for meaningful comparisons across muscles, tasks, and individuals. Despite certain methodological limitations, EMG remains a reliable tool in clinical diagnostics, rehabilitation, and performance analysis [10,11].

While numerous studies have explored gluteus maximus activation during various resistance exercises, there remains a lack of direct comparison between different hip extension positions in asymptomatic individuals using standardized EMG protocols. Most existing literature focuses on loaded movements or clinical populations, leaving a gap in understanding how posture alone influences gluteal activation. Addressing this gap is essential for optimizing exercise selection in both rehabilitation and performance contexts. Therefore, the present study aims to compare gluteus maximus EMG activity across three distinct hip extension positions prone lying, half-prone, and squatting in healthy adults.

## METHODS

### *Study design:*

The study was designed as a cross-sectional observational study.

A priori power analysis was conducted using G*Power software version 3.1.9.4 (Windows platform) to determine the required sample size. The analysis assumed an alpha level of 0.05, a statistical power of 95%, and an effect size of 0.35 based on previous literature. A repeated measures ANOVA (within-subjects design) was selected as the statistical test to compare EMG activity of the gluteus maximus across three different positions. The analysis indicated that a minimum sample size of forty-five participants was required, which was achieved in the current study.

**Ethical consideration**

The Research Ethical Committee of the Faculty of Physical Therapy, Cairo University (NO: P. T. REC/012/005430), a written consent form was acquired from participants before to their involvement in this study.

### *Participants:*

A total of forty-five healthy volunteers (both male and female), aged between 18 and 45 years, were recruited and assigned to a single group. Participants were selected based on the following criteria:

**Inclusion criteria**:

- Asymptomatic individuals with a body mass index (BMI) ranging from 18 to 25.

**Exclusion criteria**:

- History of hip joint or lower back surgeries, trauma, or deformities.

- Medical conditions contraindicating EMG use (e.g., cancer, uncontrolled diabetes mellitus, hypertension).
- Neurological disorders involving upper or lower motor neuron lesions.
- Females during pregnancy.
- Cardiovascular or respiratory disorders.
- Chronic low back pain.
- Any prior abdominal surgeries.

***Outcome measures:***

The root mean square (RMS) of the gluteus maximus muscle during maximum voluntary isometric contraction (MVIC) was assessed from three postures for the dominant leg.

**Instrumentation and procedures for evaluation:**

**I.The device components:**

**Amplifiers**: Two electrically independent amplifier channels having an impedance of less than 100 mΩ and a sensitivity of up to 4000 µV/0.5. The amplifier supports up to ten traces on the screen, with a resolution of 1000 points per trace.

**Electrodes**: one line have the three electrodes divided as the following

**1)** The black electrode is the negative electrode.
**2)** The red electrode is the positive electrode.
**3)** The green electrode is the ground electrode.

Before the apparatus was used, the commit company **Nuo Cheng China (NCC)** calibrated all tested parameters**.**

**II.Exercise mat and a plinth.**

**Evaluation procedures:**

**The subjects were assessed in 3 positions for the dominant leg:**

1-Prone Lying Position.
2-Half prone position (90°hip flexion).
3-Getting up from squatting position (90° knee flexion).

**Preparation:**

- Subjects rehearsed each testing posture multiple times until they were acquainted with the poses.

- Participants were instructed to wear suitable attire, predominantly shorts, to provide access to the EMG electrode implantation sites.

The skin was washed with a 70% isopropyl alcohol wipe and permitted to dry, thereby increasing electrode adhesion and reducing skin impedance to improve EMG signal quality [12].

- Superfluous hair was excised with a razor if necessary, and the skin was sanitized and abraded with an alcohol swab.

-Self-adhesive, disposable rectangular snaps were applied to the skin surface of the subjects.

**Position of surface and ground electrode:**

The position of the surface and ground electrodes is crucial for accurate signal acquisition.

**Surface electrodes** were used to capture the electrical activity of the gluteus maximus muscle from the skin surface.

- Electrode 1 **(negative)**: The first electrode was placed horizontally, just above the gluteal fold and approximately at the midpoint between the body's midline and the greater trochanter aligning with standard landmarks for optimal EMG signal detection [13].
- Electrode 2 **(positive)**: The second electrode was oriented vertically and positioned just below the first electrode in the upper outer quadrant of the gluteal fold, in accordance with updated surface EMG placement protocols for the gluteus maximus [14].
- Ground Electrode **(green):** The ground electrode served as a reference point for the EMG system and helps reduce noise and interference. It was be placed at a location devoid of significant muscle activity. The recommended placement for the ground electrode in gluteus maximus EMG recordings.

To reduce interference from adjacent muscle activity and capitalize on anatomical stability, the ground (reference) electrode was positioned over a bony prominence the anterior superior iliac spine, a component of the iliac crest [15].

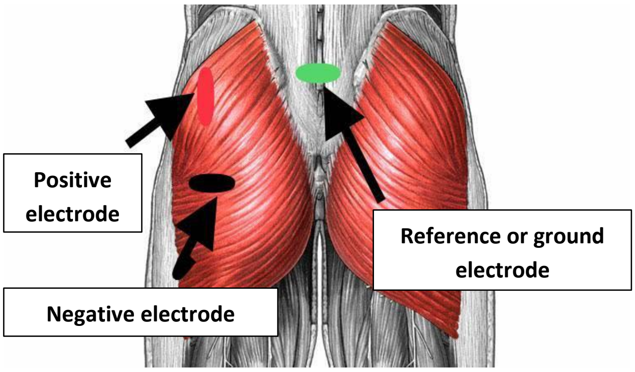


**Fig: The position of the surface and ground electrodes**

These electrodes have good contact with the skin and adhered firmly to minimize movement artifacts and ensure reliable signal acquisition.

**Assessment of muscle amplitude at resting position (starting position):**

- All the participants were learnt how to relax their gluteus maximus muscle from each position before any trials or contraction through eye contact with the system to the laptop screen and watch the signal and number of root mean square (RMS) appeared on the screen which shouldn't exceed 30 microvolts (minimal muscle tension) considering (NCC) company recommendations.
- The participant was instructed to relax fully while their resting EMG amplitude was recorded in three separate trials, with the average value subsequently calculated to establish a stable baseline [16].
- The root mean square (RMS) amplitude or peak-to-peak amplitude of the EMG signal was extracted during resting conditions to quantify the overall magnitude of muscle activity, providing a baseline measure for subsequent analysis [17].

**Assessment of muscle amplitude at maximum voluntary isometric contraction**

The subject lay prone while manual resistance was applied during MVIC testing to prevent joint movement while allowing participants to exert maximal effort. The resistance was adjusted individually above knee joint with no knee flexion or pelvic rotation based on each participant's strength to ensure that the contraction remained isometric. Resistance was tailored to each participant's strength to maintain a static joint position and ensure a true isometric contraction. For weaker individuals, minimal resistance was sufficient to stabilize the limb, whereas stronger participants required bilateral manual resistance to maintain joint position. This approach ensured accurate EMG signal acquisition without compromising the isometric nature of the contraction.

Each contraction was sustained for five seconds and repeated three times, with thirty second rest intervals between repetitions to reduce fatigue and improve measurement consistency[18]. During these maximal voluntary isometric contractions (MVICs), the EMG signal was recorded for the same five-second duration to ensure a representative sampling of maximal muscle activation[19].

**Assessment of muscle amplitude at prone straight leg raising**

all subjects performed straight leg raising from prone and the number of RMS was taken.

**Assessment of leg extension from half prone (prone table hip extension with 90 degrees knee flexion).**

- All subjects performed leg extension from half prone on plinth with knee flexion 90 degrees and RMS was taken.
- Knee flexion during hip extension exercises can influence the relative activation of the gluteus maximus and hamstrings. Specifically, increasing knee flexion tends to enhance gluteus maximus activation while reducing hamstring involvement, thereby minimizing hamstring coactivation and potentially reducing the risk of strain [20,21,22].

**Assessment of getting up from squat.**

- All participants performed squats to achieve 90 degrees of knee and hip flexion. Root Mean Square (RMS) values of the electromyographic (EMG) signals from the gluteus maximus were recorded during the upward (ascending) phase of the squat, starting from the initiation of the upward movement[23,24,25]. This measurement was repeated three times, with approximately 30 seconds of rest between trials, in accordance with standard practices in electromyography research[26].

**Analysis of EMG data:**

Prior to analysis, EMG signals were visually inspected using amplitude-time plots to identify and correct potential artifacts, including DC offset, motion disturbances, and electrode noise [27]. To ensure valid comparisons across muscles, individuals, and experimental conditions, the EMG data were normalized using the root mean square (RMS) method. Normalization mitigates variability due to factors such as muscle size, subcutaneous fat, and electrode placement [28]. In this study, RMS values recorded during each test position were normalized against the RMS obtained during a maximal voluntary isometric contraction (MVIC) of the gluteus maximus in the prone position. The normalized EMG amplitude was calculated by dividing the RMS of each test position by the RMS of the MVIC reference, then multiplying by 100 to express the result as a percentage of maximum activation [%MVIC][29,30].

*Normalized RMS %=EMG amplitude during resting (from each position) / EMG amplitude MVIC from prone *100.*

Note: EMG amplitude = RMS

This normalization process enables meaningful comparisons of muscle activation across individuals or between different testing sessions [31].

***Statistical analysis***

The Shapiro-Wilk and Levene's tests were employed to verify data normality and evaluate group homogeneity of variances. The data exhibited a normal distribution, and the variance was homogeneous. Repeated measures ANOVA was employed to assess the impact of various positions on EMG activity of the gluteus maximus: prone lying, half prone, and rising from a squat. Post-hoc testing with the Bonferroni correction was conducted for multiple comparisons. The significance level for all statistical tests was set at a p-value of 0.05. SPSS version 23 was utilized.

**Demographic Characteristics: Table (1,2) showed the subjects characteristics of study group.**

Repeated measure ANOVA analysis revealed that there was statistically significant difference between EMG gluteus Maximus activity in three different positions as Wilk's A = 0.65, $F_{(2, 43)}$ =11.68, P-value < 0.001, Partial Eta Squared ($\eta^2$) = 0.35.

**Table (1): General characteristic of participants (N=45) ***

| | $\overline{X}$ ±SD | Maximus | Minimum |
|---|---|---|---|
| Age (years) | 26.09 ± 5.69 | 40 | 18 |
| Weight (kg) | 74.96 ± 9.08 | 82 | 54 |
| Height (cm) | 169.8 ± 7.91 | 190 | 159 |
| BMI (kg/m²) | 23.56 ± 1.96 | 25 | 19.03 |
| Working hours | 8.733 ± 2.3 | 12 | 4 |

***: Data were expressed as mean ±Standard deviation. N: number. BMI: body mass index.kg: kilogram. cm: centimeter. Kg/m²: kilogram per meter square.**

**Table (2): The frequency distribution of sex and occupation distribution for study group (N=45) ***

| | Sex distribution | | | | |
|---|---|---|---|---|---|
| | Males | | Females | | |
| No. (%) | 26 (57.78%) | | 19 (42.22%) | | |
| | *Occupation distribution* | | | | |
| | Doctors | Pharmacists | Students | Teachers | Physical therapists |
| No. (%) | 9 (20%) | 4 (8.89%) | 13(28.89 %) | 15(33.33 %) | 4 (8.89%) |
| Total | 45 (100%) | | | | |

**Data are expressed as n (%).**

**Table (3): Descriptive statistics of EMG gluteus Maximus activity from different positions (N=45) ***

| EMG gluteus Maximus activity (RMS%) | $\overline{X}$ ±SD | Maximum | Minimum |
|---|---|---|---|
| prone lying position | 110.59 ± 16.95 | 201.14 | 63.58 |
| Half prone position | 87.12 ± 13.52 | 179.59 | 39.8 |
| Getting up from squatting position | 89.06 ± 20.69 | 180.69 | 45.6 |

***: Data were expressed as mean ±Standard deviation. N: number, RMS: root mean square.**

**Table (4): comparison between RMS of EMG gluteus Maximus activity from different positions (N=45) ***

| EMG gluteus Maximus activity (RMS%) | prone vr half prone | Prone vs squatting | Half prone vs squatting |
|---|---|---|---|
| p-value | 0.001 | 0.01 | 0.98 |
| MD (95% CI) | 23.47(9.56,37.38) | 21.53(3.63,39.43) | -1.94(-23.23,19.36) |

***: Data were expressed as mean ±Standard deviation. N: number, RMS: root mean square. MD, Mean Difference; CI, confidence interval; P-Value < 0.05 indicates statistical significance.**

## DISCUSSION:

The gluteus maximus (GMax) is the largest and most powerful muscle in the gluteal region, playing a critical role in strength, movement, and functional stability [32]. Functionally, it contributes to motion across all planes, and alterations in its morphology or activation particularly in the context of pelvic muscle dysfunction may impair physical performance and predispose individuals to degenerative conditions [32,3]. Isawa et al. [33] reported that patients with hip osteoarthritis exhibited significant gluteal muscle atrophy and fatty infiltration, with GMax volume correlating strongly with early postoperative functional outcomes. These findings suggest that targeted preoperative rehabilitation aimed at enhancing gluteal muscle hypertrophy may facilitate improved recovery in the early postoperative phase. Furthermore, hip extension is a fundamental movement in both daily activities and athletic performance, with gluteus maximus activation increasing under higher resistance and during explosive actions such as sprinting and jumping [34]. Resistance exercises like squats and hip thrusts primarily engage the gluteus maximus while minimizing hamstring involvement, making them effective strategies for gluteal strengthening [35,36].

Recent research has confirmed the value of prone hip extension (PHE) tests for evaluating gluteus maximus activation under varying conditions, found that performing prone hip extension with pelvic fixation significantly increases both gluteus maximus activation and the gluteus to hamstring activation ratio compared to no fixation [33]. Several studies have emphasized the importance of standardizing hip positioning during prone gluteus maximus maximal voluntary isometric contraction (MVIC) assessments. While the optimal position for gluteus maximus maximum voluntary isometric contraction (MVIC) is hypothesized to be full hip extension or hip hyperextension. The prone position is presently the preferred posture in various texts on muscle testing [37]; nevertheless, to the authors' knowledge, this position has not been evaluated against others in the literature. Performing prone hip extension with the hip flexed at approximately 70° has been associated with reduced gluteus maximus EMG amplitude, whereas positions closer to full or end-range hip extension elicit significantly higher activation levels [38,39]. These findings highlight the critical role of precise joint positioning in accurately assessing and maximizing gluteus maximus activation during MVIC testing.

While previous studies have highlighted the influence of pelvic fixation and hip positioning on gluteus maximus activation during prone hip extension, the current study expands on this by examining EMG amplitude across multiple functional positions, including squatting and half-prone postures. Unlike earlier research that focused solely on prone configurations, this study provides comparative data on gluteus maximus activation under varied biomechanical demands, offering broader insights into functional recruitment patterns relevant to rehabilitation and exercise prescription.

Conversely, extended knees facilitate a broader range of hip extension compared to flexed knees, resulting in a more significant shortening of the gluteal fibers and consequently an increased level of gluteus maximus EMG activity [40]. They discovered that complete hip extension produced the highest gluteus maximus EMG activity.

A recent study by smith et al. [41] supports this finding, indicating that performing prone hip extension with extended knees leads to higher gluteus maximus electromyographic (EMG) activity. These results underscore the importance of knee positioning in optimizing gluteal muscle activation during rehabilitation and strength training exercises.

Prone is an open kinetic chain exercise with the body secured on a bench, while squeeze is a closed kinetic chain exercise executed in an upright position. A study comparing muscle activation between open and closed kinetic chain exercises found that closed-chain movements elicit broader multi muscle engagement than open chain tasks, including greater overall lower limb activation, raising questions about whether gluteus maximus EMG would be inherently higher or lower between these modes [42].

The prone hip MVIC extension test required manual resistance from the examiner to maintain a static position during contraction, whereas the squeeze test relied on the anatomical structures surrounding the hip to provide resistance against hip extension. The impact of such anatomical constraints on EMG activity remains unclear, as no prior studies have specifically examined the influence of restricted range of motion due to internal anatomical resistance rather than external force on muscle activation levels [42].

Jeon et al. 43 conducted a study comparing three prone hip extension exercises: traditional prone hip extension, prone table hip extension, and prone table hip extension with ninety-degree knee flexion. Surface electromyography was employed to assess the activity of the gluteus maximus, biceps femoris, semitendinosus, and erector spinae muscles. Kinematic data were acquired to investigate compensatory pelvic motion. The principal conclusion was that gluteus maximus activity was markedly elevated during prone table hip extension (half prone) with ninety degrees of knee flexion. Muscle activity rose by approximately 70.9 percent compared to basic prone hip extension and by 13.75 percent compared to prone table hip extension without knee flexion (both comparisons achieved $p < 0.01$), with no significant alterations in pelvic mobility between the positions.

Kang et al. 44 investigated gluteus maximus activation during prone hip extension with knee flexion (PHEKF) at a neutral hip position (0° abduction). Participants were placed in a prone position on a table, with the hip joint oriented at the edge to provide unrestricted sagittal motion. The hip was positioned in neutral (0° abduction), and the knee was flexed at approximately 90°. From this position, individuals executed pure hip extension by elevating the thigh upward. Surface electromyography (EMG) was recorded, and the root mean square (RMS) amplitude for the gluteus maximus was computed and standardized to percentage of maximum voluntary isometric contraction (%MVIC). Under this circumstance, the mean GM activation was approximately 43.9% MVIC, signifying successful isolated activation of hip extension without abduction. In a study for shin et al 39 compared EMG activity across various prone hip extension variations including prone hip extension with knee flexion with 0° abduction and reported mean gluteus maximus activation levels around **45% MVIC**, closely mirroring the earlier findings.

The present study aimed to evaluate gluteus maximus (GMax) activation during various squat conditions, with a particular focus on range of motion and external load. Findings revealed that GMax activation was significantly greater during the ascending phase of the squat, especially under high external loads (90–100% 1RM), confirming a load-dependent recruitment pattern. Additionally, squats performed through a full range of motion approximately 140° of knee flexion elicited higher EMG amplitudes compared to partial squats, supporting their role in maximizing gluteal activation [45,46,47,48]. These results align with previous research indicating that deep squats consistently produce greater GMax hypertrophy than partial squats [4,46], and that habitual resistance training incorporating squats leads to significant increases in GMax volume [4].

Jeon et al. [43] and Kang et al. [44] further demonstrated that variations in hip and knee positioning during prone hip extension exercises influence GMax and hamstring activation, emphasizing the importance of joint angles in neuromuscular engagement. Moreover, neuromuscular training programs incorporating activation drills prior to squatting have been shown to enhance GMax recruitment during both bilateral and unilateral squats, with EMG activity increasing by over 50% after one week of targeted activation [49]. The current findings expand on these insights by quantifying GMax activation across different squat phases and loads, offering practical implications for strength training and rehabilitation. The increased activation during the concentric (ascending) phase may reflect the biomechanical demand placed on the hip extensors when rising from deep flexion under resistance, as confirmed by normalized RMS values showing 1.1–1.2 times greater activity during ascent compared to descent [50].

These differences may be attributed to changes in muscle length-tension relationships and joint mechanics, underscoring the need for individualized squat programming to optimize gluteal development. However, limitations include reliance on surface EMG, which may be affected by signal cross-talk, and the use of a trained female sample, which may limit generalizability. In summary, the study reinforces the effectiveness of deep squatting under high loads for enhancing GMax activation and provides evidence-based guidance for exercise prescription in both athletic and clinical settings.

The findings of this study suggest that clinicians may consider incorporating straight leg raises (SLR) from the prone position into rehabilitation programs for patients with gluteus maximus weakness or those recovering from hip surgeries. This movement effectively isolates the gluteus maximus, allowing for targeted strengthening with minimal compensatory activation from surrounding muscles. Additionally, exercises such as prone table hip extension and transitioning from a squat position may serve as more functional options, engaging multiple muscle groups and joints simultaneously. These movements could be particularly beneficial for individuals aiming to enhance overall functional patterns or for athletes requiring dynamic training of the glutes, quadriceps, and hamstrings. Furthermore, the use of surface electromyography (sEMG) is supported as a valid method for assessing gluteus maximus activation, offering clinicians a reliable tool for monitoring muscle engagement during rehabilitation.

Despite its strengths, this study had several limitations. The relatively small sample size may have limited the statistical power and reduced the generalizability of the findings to broader populations; a larger sample could provide more robust insights, particularly regarding subtle differences in gluteus maximus activation across positions. Additionally, the cross-sectional design assessed muscle activity during a single trial of each movement, which restricts understanding of how activation patterns may evolve over time or with repeated exposure. Furthermore, participant training history and prior exercise experience were not controlled for, potentially influencing EMG outcomes. Future research should explore longitudinal effects of repeated exposure to these exercises, variations in squat depth and prone hip extension techniques, and the influence of training status on muscle activation. Comparative studies across exercise types and clinical populations could further clarify the therapeutic potential of gluteus maximus training.

## CONCLUSION

The study concluded that the prone lying (straight leg raising) position elicited the highest gluteus maximus activation among the tested conditions, emphasizing the importance of exercise positioning in optimizing gluteal recruitment. Prone-based movements may be beneficial in early phase rehabilitation, particularly for individuals with pelvic instability or low back pain.

## DECLARATIONS


- **Consent to publish:** I certify that each author has given their consent to submit the work.
- **Funding:** This study did not obtain any external financial support.
- **Conflict of interest interests:** The authors have no conflict of interest.


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