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EFFECT OF DIFFERENT HIP AND SHOULDER ANGLES ON ELECTROMYOGRAPHIC ACTIVITY OF GLUTEUS MAXIMUS AND LOWER TRAPEZIUS MUSCLES

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ABSTRACT

The Gluteus Maximus muscle is crucial for various functional movements, serving as both a trunk and hip extensor. If this muscle becomes weak, it can lead to problems with pelvic and hip joint function, as well as contribute to lower back pain. The prone hip extension (PHE) exercise is widely utilized in clinical settings due to its effectiveness in activating the Gluteus Maximus muscle. To compare the changing of hip and shoulder angles on electromyographic activity of the Gluteus maximus muscle and the contralateral lower fibers of the Trapezius muscle and to correlate between the activity of the Gluteus maximus muscle and the contralateral lower fibers of the Trapezius muscle. Thirty-one healthy adults according to sample size calculation, after achieving the inclusion and exclusion criteria, their age ranged from 18 and 25 BMI were 20.8-24.4 an informed consent was filled out by each participant before the beginning of the study. Thirty-one subjects were allocated to perform prone hip extension (shoulder abduction angles of 125°, hip flexion angle of 20° and combined shoulder abduction of 125° and hip flexion 20°). The study's results indicated a statistically significant difference in Gluteus Maximus EMG activity among the three positions (PHE with a 125° shoulder abduction angle, PHE with a 20 hip flexion angle, and PHE with a 125° shoulder abduction angle combined with a 20 hip flexion angle), favoring position 3. Additionally, there was a statistically significant difference in Lower Trapezius EMG activity among the three positions, also favoring position 3. Prone hip extension with a 125° shoulder abduction angle combined with a 20 hip flexion angle is recommended as the position for maximizing activation of both the Gluteus Maximus and Lower Trapezius muscles.

Key Words: Electromyographic activity of Glutes maximus- Electromyographic activity of lower trapezius

INTRODUCTION

The Gluteus Maximus muscle is crucial for various functional movements, serving as both a trunk and hip extensor. If this muscle becomes weak, it can lead to problems with pelvic and hip joint function and contribute to lower back pain **(Buckthorpe, *et al.*, 2019).**The prone hip extension (PHE) exercise is widely utilized in clinical settings due to its effectiveness in activating the Gluteus Maximus muscle **(Yoon, *et al.*, 2015).** Nevertheless, during prone hip extension (PHE), undesired compensatory movements like pelvic anterior tilt or excessive lumbar extension may occur. These compensations could be attributed to tightness in the hip flexors, dominance of the erector spinae (ES), or weakness in the Gluteus Maximus muscle. Hence, recent research has directed attention toward methods to manage and control unwanted substitution movements of the pelvis and lower back during prone hip extension exercises **(Rainsford, 2015).** Numerous previous studies on prone hip extension have been conducted with the hip flexed at a 0° angle, as joint position can significantly impact muscle contraction by altering muscle length **(Oh, 2014).** Other studies have explored starting positions ranging from 20° to 90° of hip flexion, particularly for individuals with hip flexor contracture. These variations in starting positions reflect efforts to accommodate differing anatomical conditions and optimize the effectiveness of the exercise **(Rainsford, 2015).** The prone hip extension has been executed with diverse interventions and positions to engage the Gluteus Maximus. However, there's a scarcity of information regarding whether hip joint angles during prone hip extension selectively alter the electromyographic (EMG) activity of the Gluteus Maximus. Research suggests that a hip flexion angle of 20° may be the optimal position to selectively activate the Gluteus Maximus, as it helps minimize additional pelvic anterior tilt **(Yoon, *et al.*, 2015).**The position of the shoulders during prone hip extension (PHE) significantly influences the activation of posterior oblique myofascial sling muscles and contributes to the stabilization of the lumbopelvic region **(Ha and Jeon (2019).** In particular, research indicates that performing prone hip extension coupled with 125° of shoulder abduction leads to increased activation of lumbopelvic stabilizing muscles, including both the multifidus and ipsilateral Gluteus Maximus. This position also results in decreased pelvic compensatory rotation compared to prone hip extension with lower shoulder abduction angles. It sounds like our study aims to fill an important gap in the existing literature by investigating the optimal position for maximizing activation of the Gluteus Maximus muscle during prone hip extension. By comparing the effects of 20-degree hip flexion, and 125-degree shoulder abduction, and their combination, we will provide valuable insights into how different joint positions influence muscle activation. This research could have significant implications for exercise prescription and rehabilitation strategies aimed at targeting the Gluteus Maximus effectively. The present research findings shed light on the interconnectedness of muscles in the back, challenging the conventional notion that back muscles operate as independent units during specific movements, **(Marpalli, *et al.*, 2022).**

MATERIALS AND METHODS

Study design, setting and participants:

A cross-sectional study was conducted at the Electromyography Lab of the Faculty of Physical Therapy, Cairo University, to investigate the effect of different hip and shoulder angles on electromyographic activity of Gluteus maximus muscle and the contralateral lower fibers of the Trapezius muscle during prone hip extension. Thirty-one healthy adults according to sample size calculation, after achieving the inclusion and exclusion criteria, each participant filled an informed consent before the beginning of the study. Thirty-one subjects were allocated to perform prone hip extension (shoulder abduction angles of 125°, hip flexion angle of 20° and combined shoulder abduction of 125° and hip flexion 20°).

Inclusion criteria: Thirty-one healthy adults **(Cohen, 2013).** Age of subjects between 18-25 years **(Arab, *et al.*, 2017),** and BMI was 20.8-24.4 **(Ha and Jeon 2019)**.

Exclusion criteria: If there's been any occurrence within the last year of lower back discomfort, shoulder discomfort, issues with lower limb function, anterior cruciate ligament strain, patellofemoral pain syndrome, chronic instability in the ankle, or any bone fractures, **(Ha and Jeon 2019)**, and If there is pain in any region during exercises in this study **(Ha and Jeon 2019).**

Instrumentation:

Neuro-MEP.NET EMG Surface apparatus**,** the amplitude of GM during the prone hip extension (PHE) test will be recorded using two EMG channels (Neuro-MEP.NET, Neurosoft, Ivanovo, Russia)—version 4.1.7.0 software. **Amplifiers**: The apparatus featured two electrically isolated amplifier channels with an impedance of less than 100 m ohm and sensitivity of up to 4000 UV/0.5. The amplifiers allowed for gains and displayed up to ten traces on screen, each with a resolution of 1000 points per trace.

Before use, the contracting company calibrated all tested parameters of the apparatus. **Electrodes**: Ground electrodes are used, and two silver surface recording electrodes (one active and the other passive) for bipolar configuration. As it is reusable, it should be sterilized before usage. The concave aspect was applied to the skin with a contact gel and stabilized by adhesive strips after enough pressure was applied to ensure good electrode contact**. Feedback bar**: The apparatus was custom-designed and locally manufactured to offer feedback to the patient during controlled prone hip extension exercises, as recommended by the guidelines, **(Cochrane, 2013).**

Procedures: Before the measurements, subjects were instructed to engage in sub-maximal speed jogging for 5 minutes as a warm-up. This warm-up routine was aimed to prevent potential discomfort or pain associated with the test exercises **(Serner, *et al.,* 2014)**. The dominant leg, typically the preferred limb for kicking a soccer ball, was utilized for the exercise **(Ayotte, *et al.,* 2007)**. Thirty-one subjects were divided into groups to perform prone hip extension (PHE) under different conditions: shoulder abduction of 125°, hip flexion of 20°, or a combination of both hip flexion of 20° and shoulder abduction of 125°. Each subject was instructed to execute the task until reaching a hip extension angle of 10°, aligning with the placement of the target bar in the prone position. During the isometric phase of the exercise, electromyography (EMG) data were collected for 5 seconds. However, only the measurements obtained during the middle 3 seconds were utilized for data analysis. This approach was aimed to mitigate any potential effects stemming from the initiation or termination of the exercise or from the connection elements of the skin-electrode **(Sykes, and Wong, 2003).** The dominant leg of each subject, defined as the preferred limb for kicking a soccer ball, was consistently utilized during all exercises **(Ayotte, *et al.,* 2007).** Thus, subjects were instructed to lift their dominant leg after maintaining the initial position for 5 seconds. The hip extension was sustained for a minimum of 5 seconds with contact made on the bar. Each exercise consisted of three consecutive repetitions, with a rest period of 3 minutes between exercises to mitigate muscle fatigue, **(Bussey, *et al.,* 2018).**

PHE with a 125° shoulder abduction angle: The subject was positioned in the prone position on the table with both arms comfortably placed beside the trunk. They were then instructed to perform contralateral shoulder abduction to 125° and external rotation while holding a 1 kg load before commencing prone hip extension (PHE). This action was intended to activate the contralateral lower trapezius. Following this activation, the subjects proceeded to perform PHE until their dominant heel made contact with the target bar. The hip joint was extended to 10° with knee extension, ensuring contact with the target bar, and maintained in this position for 5 seconds before slowly returning to the starting position **(Ha and Jeon (2019).**

PHE with a 20 hip flexion angle: Each subject was positioned prone on an adjustable table that permitted the subject's hip to be initially flexed at 20°. Subsequently, subjects executed prone hip extension (PHE) until their dominant heel made contact with the target bar. The hip joint was extended to 10° with knee extension, ensuring contact with the target bar, and maintained for 5 seconds. Finally, subjects slowly returned to the starting position, **(Yoon, *et al.,* 2015).**

PHE with a 125° shoulder abduction angle combined with a 20 hip flexion angle: In this position, the two previous positions were combined. Subjects were instructed to execute prone hip extension (PHE) until their dominant heel made contact with the target bar. The hip joint was extended to 10° with knee extension, ensuring contact with the target bar, and maintained for 5 seconds. Subsequently, subjects slowly returned to the starting position.

Electrode placement and procedure for recording EMG activity: Before applying the EMG electrodes, any necessary shaving of the skin at the anatomical landmarks was performed, followed by rubbing and cleaning with 70% isopropyl alcohol to eliminate excess oils and debris. The electrodes were sterilized and positioned on the muscle belly, aligned parallel to the muscle fibers and away from the tendon and muscle edges, with an inter-electrode distance of two centimeters. Adhesive tape was used to secure the electrodes in place. Skin impedance was assessed to ensure it was less than 5 kΩ before recording, **(Mohamed, *et al.*, 2022).** For the gluteus maximus, electrodes were positioned midway between the greater trochanter and the second sacral vertebra. They were placed at an oblique angle, either at or slightly above the level of the trochanter **(Plummer, *et al.*, 2017).** To locate the lower trapezius muscle, identify it at around two-thirds of the distance from the base of the spine of the scapula to the eighth thoracic vertebra. This point is typically situated approximately 5 centimeters below the base of the spine of the scapula **(Hermens *et al.*, 1999 and Dankaerts, *et al.*, 2004).**

Two normalization procedures were employed: The standard maximal voluntary isometric contraction (MVIC) method, conducted by SENIAM Guidelines (www.seniam.org), and the submaximal voluntary contraction (sub-MVC) task, which involved performing prone double leg raises **(Ha, and Jeon, 2021)**. It was advised to refrain from maximal contractions of the gluteus maximus (GM) muscle to prevent the possible reproduction of pain during testing. This precaution was taken to ensure the validity of using root mean square (RMS) values for normalization, **(Ha, and Jeon, 2021)**. For the sub-MVC of GM, the subjects were asked to lift both knees 5 cm off the examination table while the knees were flexed at 90 and held for 5 seconds in a prone position. Three trials were performed with 30 seconds of rest in between.

PHE Test: Before testing, all subjects received instructions on active prone hip extension (PHE) and were given ample time to familiarize themselves with the exercise. All electromyography (EMG) measurements were conducted with subjects lying prone on a therapeutic table with a firm mattress. Subjects were instructed to lie prone with their arms at their sides and maintain a neutral position of the pelvis and hip joint. The target angle for hip extension was set at 10 degrees to standardize the amount of hip extension.

A goniometer was utilized to determine when the leg reached 10 degrees of extension to isolate the hip extensors. A specially designed adjustable metal bar was employed to provide feedback when the hip extension reached 10 degrees, with the horizontal component adjusted accordingly for each subject. Subjects were verbally instructed when their hip extension reached 10 degrees. Throughout the PHE task, visual supervision ensured that subjects maintained a neutral pelvis position, hip extension, and knee extension. Any visible hip or pelvic rotation movements led to data exclusion. A 30-second rest period was given between each trial, **(Cochrane, 2013)**. EMG signal analysis the signals were full-wave rectified and bandpass (5-500 HZ) filtered, sampled at 1000 HZ, and then the root mean square (RMS) was calculated **(Plummer, *et al.*, 2017).**Data were expressed as mean± SD. Descriptive statistic was used for the subjects' characteristics of the study group. The Shapiro-Wilk test was used to evaluate data distribution and to test for normality. Repeated measure ANOVA was used to compare between measured variables. Person correlation coefficient relation was used to determine the relation between Gluteus Maximus and Lower trapezius EMG activity at the three different positions. Statistical package for the social sciences computer program (version 20 for Windows; SPSS Inc., Chicago, Illinois, USA) was used for data analysis. *P* less than or equal to 0.05 was considered significant.

Subject characteristics: In this study, thirty-one healthy adults were allocated to perform prone hip extension (shoulder abduction angles of 125°, hip flexion angle of 20° and combined shoulder abduction of 125° and hip flexion 20 **(Table 1**).

Table (1): General characteristics of subjects in the study group

Subjects characteristics Study group (n=31)	Mean ± SD	Minimum	Maximum
Age (years)	**23.2± 1.5**	**21**	**25**
Weight (kg)	**63.4± 7.4**	**50**	**82**
Height (cm)	**167.8± 9.7**	**148**	**186**
BMI (kg/m^2)	**22.5± 2**	**18.7**	**25**
Sex distribution	**Males 15 (48%), Females 16 (52%)**		

Gluteus Maximus electromyographic activity: There was a statistically significant difference in Gluteus Maximus EMG activity between the three positions (P=0.001) **(Table 2).** Post hoc test for pairwise comparison, there were significant differences between position 1 and 2 (P=0.001) in favor to position 2, between position 1 and 3 (p=0.001) in favor to position 3 and between position 2 and 3 (p=0.001) in favor to position 3 **(Table 3).**

Lower trapezius electromyographic activity: There was a statistically significant difference in Lower trapezius EMG activity between the three positions (P=0.001) **(Table 2) ,** there were significant differences between position 1 and 2 (P=0.001) in favor to position 2, between position 1 and 3 (p=0.001) in favor to position 3 and between position 2 and 3 (p=0.001) in favor to position 3 **(Table 3)** .

Table (2): EMG activity of Gluteus Maximus and lower trapezius at different positions

Position / Measured variables	EMG activity ()	
	Gluteus Maximus	Lower Trapezius
(Position 1) PHE with a 125° shoulder abduction angle	16± 5.7	15± 6.6
(position 2) PHE with a 20 hip flexion angle	25.7± 5.4	27.6± 6.2
(position 3)PHE with a 125° shoulder abduction angle combined with a 20 hip flexion angle	34.6± 7.2	66.4± 5
F- value	69.7	625
P- value	0.001	0.001

Table (3): Bonferroni test between different positions

Post hoc test (Bonferroni)		Gluteus Maximus	Lower trapezius
Position 1 vs. Position 2	Mean difference p-value	-9.7 0.001	-12.5 0.001
Position 1 vs. Position 3	Mean difference p-value	-18.6 0.001	-51.4 0.001
Position 2 vs. Position 3	Mean difference P-value	-8.9 0.001	-38.8 0.001

Correlation between the activity of the Gluteus Maximus muscle and the contralateral lower fibers of the Trapezius muscle: There was no significant direct weak correlation between Gluteus Maximus and Lower trapezius EMG activity at position 1(r= 0.317) (p=0.082). While there was a significant direct weak correlation between Gluteus Maximus and Lower trapezius EMG activity (r= 0.367) (p=0.042) at position 2 and there was a significant direct strong correlation between Gluteus Maximus and Lower trapezius EMG activity at position 3 (r=0.598) (p=0.001) **(Table 4).**

Table (4): Pearson Correlation between Gluteus Maximus and Lower trapezius EMG activity at the three different positions.

		Lower trapezius		
		Position 1	Position 2	Position3
Gluteus Maximus	r value p-value	0.317 0.082	0.367 0.042*	0.598 0.001*

RESULTS AND DISCUSSION

The study's results indicated a statistically significant difference in Gluteus Maximus EMG activity among the three positions (PHE with a 125° shoulder abduction angle, PHE with a 20-hip flexion angle, and PHE with a 125° shoulder abduction angle combined with a 20-hip flexion angle), favoring position 3. Additionally, there was a statistically significant difference in Lower Trapezius EMG activity among the three positions, also favoring position 3. Furthermore, a significant strong correlation was found between Gluteus Maximus and Lower Trapezius EMG activity at position 3.

Thus, PHE with a 125° shoulder abduction angle combined with a 20-hip flexion angle was recommended as the position for maximizing activation of both the Gluteus Maximus and Lower Trapezius muscles. There are several possible explanations for our findings. Firstly, performing prone hip extension (PHE) with 125° of shoulder abduction creates a longer lever arm. This elongated lever arm increases the load

transmitted from the trunk to the pelvis. Additionally, the extended lever arm may influence the activation of the posterior oblique sling muscles, given their interconnectedness between the trunk and pelvis. Consequently, the longer lever arm associated with 125° of shoulder abduction likely facilitates activation of the same-side trunk muscles, the contralateral side of the gluteus maximus (GM), and the core muscles. This extended lever arm could lead to enhanced stabilization of the core muscles, including the multifidus and GM bilaterally, **(Myers, 2020).**
Additionally, the trapezius muscle is part of the superficial backline and shares alignment with components of the posterior oblique sling muscles, **(Myers, 2020).** Research indicates that shoulder abduction angles exceeding 110° trigger activation of the lower trapezius (lowT) muscles, **(Kang, *et al.*, 2013).** In the context of prone hip extension (PHE) with 125° of shoulder abduction, the activation of the lower trapezius (lowT) muscles could potentially enhance the co-activation of myofascial sling muscles responsible for stabilizing the thoracic and lumbar spine. Moreover, the upward and outward orientation of lowT muscle fibers suggests that shoulder abduction angles beyond 125° might aid in aligning the movement lines of muscles with their fiber lines**.** Shoulder extension combined with less than 90° of abduction leads to anterior tilting of scapular motion in the sagittal plane, **(McGill, 2015).**

Conversely, shoulder flexion accompanied by more than 100° of shoulder abduction results in scapular posterior tilting in the sagittal plane while raising the arm, **(McGill, 2015).** Hence, executing prone hip extension (PHE) with 125° of shoulder abduction allows for posterior tilting of scapular motion facilitated by lower trapezius (lowT) contraction. This mechanism leads to increased coactivation of multiple muscles within the posterior oblique sling, including the multifidus and gluteus maximus (GM), thereby aiding in lumbopelvic stability akin to guy wires, **(Martinez, 2021).** These findings clearly illustrate how shoulder positioning impacts pelvic rotational movement. Yeon Yoon proposed that a hip flexion of 20° represents the optimal position for selectively activating the gluteus maximus, as it minimizes additional pelvic anterior tilt, **(Yoon, *et al.*, 2015)**, the pelvic anterior tilt resulting from a 20° hip flexion optimizes the length of the gluteus maximus (GM) through elongation. This elongation may potentially lead to increased activity in the GM, **(Pine, 2020).**

Consequently, recent research has concentrated on managing undesired substitution movements of the pelvis and lower back during prone hip extension exercises **(Rainsford, 2015).** The position of the joint affects muscle contraction by altering muscle length. Numerous past studies on prone hip extension have been conducted with the hip in a neutral, 0° flexed position, **(Oh, 2014)**. Other studies have explored starting positions ranging from 20° to 90° of hip flexion, particularly for individuals with hip flexor contracture **(Rainsford, 2015).** The posterior oblique sling links the upper and lower body through muscular and myofascial connections, **(Cochrane, 2013).** It consists of connections between the gluteus maximus, thoracolumbar fascia, and the contralateral latissimus dorsi and lower trapezius. **(Joseph, *et al.*, 2014 ; McDonald, and Keir, 2015**), stated that the analogy of the sling to an elastic cable illustrates its anterior and posterior portions functioning as distinct cables. When the net force is compromised, there can be shifts in force balance, which may affect force transmission. This compromise could potentially lead to increased stiffness in the fascia, as suggested by the evidence of heightened activation in muscles such as the gluteus maximus, contralateral lower trapezius, and latissimus dorsi, indicating a nonzero net torque within the system, **(McDonald, and Keir, 2015).**

The activation of both the upper and lower trapezius muscles increased as the subject raised their arm higher. The peak activation of these muscles was observed between 90º and 120º of humeral elevation. Another study also included using an external load in two conditions, which may have contributed to the statistical significance of their findings compared to the present study, **(Nakamura, *et al.*, 2016).** Similarly, **(Nakamura, *et al.*, 2016)** reported findings consistent with ours, albeit with statistically significant effects. In their study, they applied loads of 0, 3, and 7% of the subjects' body weight. They found that lower trapezius activation was highest at elevations up to 120º, while upper trapezius activation peaked at elevations up to 90º **(Guney-Deniz, *et al.*, 2019).** Also, a study similar to our results, which also demonstrated increased activation of both the upper and lower trapezius muscles as the angle of humeral elevation increased**, (Guney-Deniz, *et al.*, 2019).**

CONCLUSION

The PHE with a 125° shoulder abduction angle combined with a 20 hip flexion angle is recommended as the position for maximizing activation of both the Gluteus Maximus and Lower Trapezius muscles**.**

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تأثير الزوايا المختلفة لمفصلي الفخذ و الكتف علي رسم العضلات للعضلة الألوية الكبيرة و الجزء السفلي من العضلة شبه المنحرفة

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تعتبر عضلة الالوية الكبيرة ضرورية لمختلف الحركات الوظيفية ، حيث تعمل كباسطة للجذع والورك. إذا أصبحت هذه العضلات ضعيفة ، فقد يؤدي ذلك إلى مشاكل في وظيفة مفصل الحوض والورك ، وكذلك المساهمة في آلام أسفل الظهر. يستخدم تمرين تمديد الورك على نطاق واسع في الإعدادات السريرية نظرا لفعاليته في تنشيط عضلة الألوية الكبيرة. الهدفمن هذا البحث هو مقارنة تغيير زوايا الورك والكتف على نشاط تخطيط كهربية العضلة عضلة الألوية الكبرى والألياف السفلية المقابلة لعضلة شبه المنحرف والارتباط بين نشاط عضلة الألوية الكبرة والألياف السفلية المقابلة لعضلة شبه المنحرف. تم اختيار واحد وثلاثون من البالغين الأصحاء وفقا لحساب حجم العينة ، بعد تحقيق معايير التضمين والاستبعاد ، تراوحت أعمارهم بين 18 و 25 وكان مؤشر كتلة الجسم 20.8–24.4 .تم ملء موافقة مستنيرة من قبل كل مشارك قبل بداية الدراسة. واحد وثلاثون شخص تم فصحهم مخصص لأداء تمديد الورك الانبطاح (زوايا اختطاف الكتف 125 درجة ، زاوية ثني الورك 20 درجة واختطاف الكتف المشترك 125 درجة وانثناء الورك 20 درجة). أشارت نتائج الدراسة إلى وجود اختلاف ذو دلالة إحصائية في نشاط الكهربي لعضلة الالويه الكبيرة بين االاوضاع الثلاثة (تمديد الورك بزاوية اختطاف كتف 125 درجة ، تمديد الورك بزاوية ثني 20 للورك ، و PHE تمديد الورك بزاوية اختطاف كتف 125 درجة مع زاوية ثني الورك 20) ، لصالح الموضع 3. بالإضافة إلى ذلك ، هناك بالإضافة إلى ذلك ، كان هناك فرق ذو دلالة إحصائية في نشاط الكهربي الجزء السفلي من العضلة شبه المنحرفة بين المواضع الثلاثة ، لصالح الموضع 3 أيضا. يوصى الباحثون في هذا البحث بتمديد الورك المعرض بزاوية اختطاف كتف 125 درجة جنبا إلى جنب مع زاوية ثني الورك 20 كوضع لزيادة تنشيط كل من عضلات الألوية الكبيرة وشبه المنحرف السفلي