BJMB
Brazilian Journal of Motor Behavior

Research Article

Electromyographic activity of the gluteus maximus during exercises of the Pilates method versus squat exercise

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https://doi.org/10.20338/bjmb.v19i1.489

HIGHLIGHTS
- The Pilates method exercises analyzed effectively activate the gluteus maximus muscle
- No superiority was observed between traditional squats and Pilates exercises regarding gluteus maximus activation
- Both traditional and Pilates-based exercises can be selected for gluteus maximus activation in rehabilitation

ABBREVIATIONS

EMG	Surface electromyography
MVIC	Maximum voluntary isometric contractions

PUBLICATION DATA
Received 09 06 2025
Accepted 18 01 2026
Published 13 02 2026

BACKGROUND: Pilates is popularly used in clinical practice for muscle strengthening, such as the gluteus maximus, for example. However, it is not known whether Pilates exercises are superior to traditional exercises.
AIM: The purpose was to investigate whether the exercises of the Pilates method present greater activation of the gluteus maximus in relation to the traditional squat.
METHODS: The study included 30 young women (age 21.63 ± 2.04 years). Initially, an anamnesis was carried out to verify the eligibility of the volunteers. Subsequently, the electromyographic signal of the gluteus maximus muscle was collected during three Pilates Method exercises (Superman; Bird Dog; Bridge) and the squat exercise. The protocol consisted of three repetitions of each proposed exercise. For data analysis, the ANOVA One Way test was applied, adopting a significance level of $p<0.05$.
RESULTS: There were no significant differences in gluteus maximus activation between the traditional squat and the Pilates exercises (superman, bird dog, and shoulder bridge; $p > 0.05$).
INTERPRETATION: These findings indicate that both types of exercises may be considered as options for promoting gluteus maximus activation in clinical settings. However, the results cannot be interpreted as evidence of muscle strengthening, since EMG amplitude does not necessarily reflect gains in strength.

KEYWORDS: Physiotherapy | Squat | Electromyography

INTRODUCTION

The Pilates method is a form of physical exercise that uses body weight and gravity to perform exercises. The Pilates method is used to improve stability, motor control, and muscle strengthening [1,5]. Several studies show that the Pilates method can be used for the treatment of musculoskeletal dysfunctions (low back pain, fibromyalgia, osteoarthritis) as well as for improving physical conditioning and promoting health [6,10].

The popularity and increasing use of the Pilates method in health clinics and rehabilitation have led to growing research for a better understanding of its effects. Pilates can be characterized by exercises with a greater emphasis on body alignment and activation of stabilizing muscles of the lumbar spine and pelvis [11,12]. Among the muscles worked in Pilates exercises is the gluteus maximus. Functionally, the gluteus maximus muscle stands out due to its important role in providing support and pelvic stabilization during hip movements in the execution of functional activities such as walking, sitting and standing, climbing and descending stairs [13]. This important stabilizing role of the gluteus maximus is due to its large cross-sectional area and its muscular functions as hip extensor, abductor, and lateral rotator [14]. Failure in the activation of the gluteus maximus can contribute to lumbopelvic instability and thus generate overloads in both the lumbar spine and other joints of the lower limb during daily tasks and predispose to pain [15].

Among the Pilates exercises used to improve gluteus maximus activation are superman, bird dog, swimming, and bridge. It is believed that applying the principles of Pilates, such as concentration, precision, coordinated breathing, and centralization, during exercise execution can generate greater muscle activation [11,16,17]. However, it is still unknown whether gluteus maximus muscle activation during

Pilates exercises is superior to that elicited by conventional exercises, such as squats, which are commonly used in clinical practice to strengthen the gluteus maximus due to their ease of execution and because they reproduce a fundamental daily movement, namely the sit-to-stand task; moreover, these exercises are performed in different body positions, which may result in different levels of muscle activation.

Therefore, this study aims to compare the amplitude of electromyographic activity of the gluteus maximus muscle during three Pilates method exercises with the conventional squat exercise. This study hypothesizes that the squat exercise would elicit greater gluteus maximus muscle activation because it is performed in an upright position, requiring the individual to lift their entire body weight, whereas Pilates exercises are performed in different body positions with partial body weight support.

METHODS

Participants

The research was a cross-sectional study. A total of thirty women were recruited to participate in the study. All participants met the following inclusion criteria: 1) were between 18 and 35 years of age; 2) were women; 3) participated in physical activity for at least 90 minutes each week. Recruits were excluded if, within the last six months, they had low back pain, lower extremity fractures or knee injuries, degenerative disease in the joints of the lower limb, report of previous surgery or trauma to the hip, knee and ankle. All individuals provided written informed consent, and the study was approved by the research ethics committee of the University of São Paulo State (66475722.4.0000.5406). The characteristics of participants are shown in Table 1.

Table 1. Demographic characteristics of participants.

Age (years)	21.63 ± 2.04
Weight (Kg)	63.10 ± 10.85
Height (m)	1.65 ± 0.06
BMI (Kg/m²)	23.06 ± 3.34

Mean ± standard deviation values.

Procedures

The evaluation procedures were carried out in a single day in the Biomechanics Laboratory. The participants were screened for the exclusion criteria. Subsequently, electromyographic evaluation of the gluteus maximus muscle was carried out during traditional squat exercise and the Pilates exercises.

Electromyographic data from the gluteus maximus muscle were analyzed during the exercise protocol. Surface electromyography (EMG) signals were recorded using an 8-channel electrode system (EMG System do Brasil®, São José dos Campos – SP, Brazil), analog band-pass filters with a cutoff frequency of 10-1000 Hz and calibrated with a frequency of 2000 Hz sampling, with 16 bits of resolution and simultaneous sampling of signals, software for data collection, processing and storage [18]. Electromyography signals of the gluteus maximus muscle were recorded from the preferred leg, which was determined by asking participants to kick a ball three times and step onto a stair three times; all participants demonstrated right-leg dominance. The electrodes were 10 mm in length and 1 mm in width and were separated by 10mm [18]. The skin was cleaned using alcohol swabs, and EMG sensors were placed according to SENIAM recommendations [19]. For normalization of the EMG data, maximum voluntary isometric contractions (MVIC) were performed. The MVIC test positions were consistent with those described by Kendall (2005), and were performed with the participant in the prone position, with the knee flexed at 90 degrees. Maximum manual resistance was applied and maintained for five seconds. The test was repeated three times with a thirty-second rest between contractions. For all participants, MVIC was averaged.

The protocol consisted of five exercises for the gluteus maximus muscle (Figure 1):

- Superman: The participant begins in a prone position with the shoulder flexed to 180° and girdle laterally rotated, elbows extended, and the radioulnar joint in a neutral position, maintaining the natural curves of the spine, as shown in Figure 1A. Upon the evaluator's command, the participant performs trunk and hip extension, raising the sternum and hands off the ground, while also lifting the feet and knees to be airborne.
- Bird Dog: In the initial position, the participant is on all fours with the left hip and knee flexed at 90°, ensuring the legs and feet are grounded. The right hip and knee are extended, and the right shoulder is flexed at 90° with the elbow extended. The left shoulder is flexed at 180°, and the elbow is extended, with the radioulnar joint in a pronated position. The participant maintains a stable position, supporting themselves on both limbs, while preserving the natural curves of the spine.
- Shoulder Bridge: The participant begins in a supine position with knees flexed at approximately 90º, feet flat on the mat and hip-width apart. The upper limbs rest extended along the sides of the body, as shown in Figure 1C. Upon the verbal command, the participant

performs hip extension, lifting the pelvis until reaching a neutral alignment between trunk and thighs.
- Squat: The participant stands with feet shoulder-width apart and arms extended horizontally in front of the body, slightly abducted, as illustrated in Figure 1D. Upon command, the participant performs a squat by flexing the hips and knees until approximately 90° of knee flexion, ensuring that the heels remain on the floor and the trunk remains aligned with a slight forward lean. The concentric and eccentric phases of the squat each lasted 4 seconds.

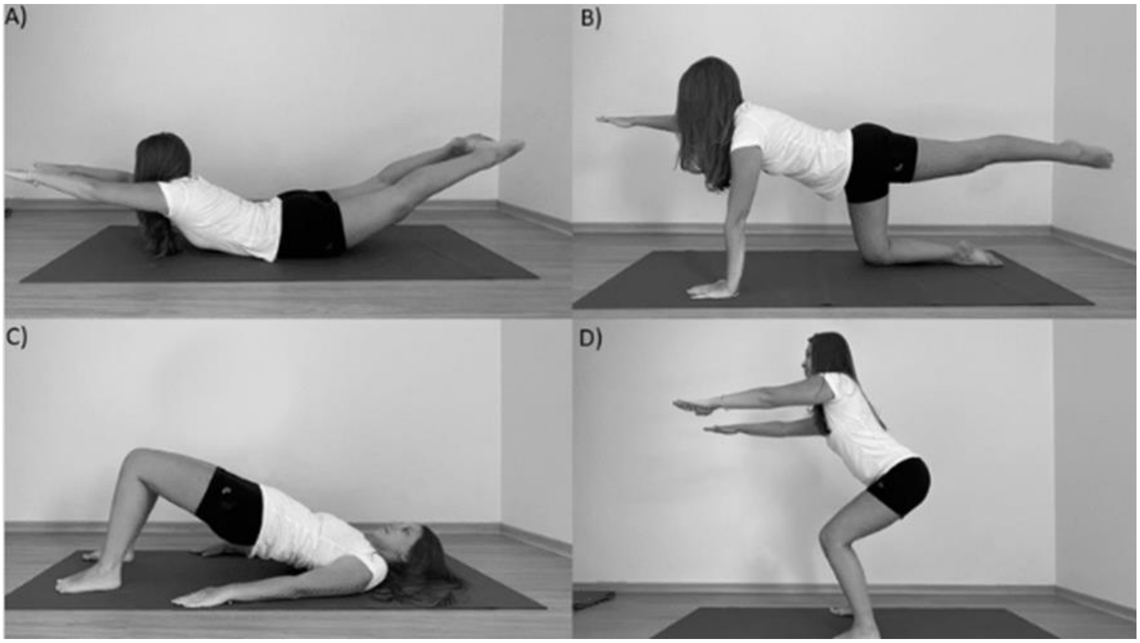

Figure 1. Exercises: superman (A), bird dog (B), shoulder bridge (C) and squat (D).

The exercise execution sequence was randomized. A metronome was used to control the speed of execution of the movement. Participants performed 3 repetitions of each exercise, with 5 seconds of rest between repetitions. Between different exercises, there was a 2-minute rest.

To analyze the electromyographic data, specific routines developed in the Matlab environment (Mathworks, Natick, MA, USA) were used. To calculate the amplitude of the electromyographic signal during the exercises, a linear envelope was created through full-wave rectification and signal smoothing, using a 4th-order low-pass filter, with a cutoff frequency of 10Hz [18]. The average of the linear envelope value was normalized by the MVIC amplitude value, and the values were expressed as a percentage of MVIC.

Statistical Analysis

Statistical analysis was performed using PASW Statistics 18.0® (SPSS) software. Normality of all dependent variables was checked. A Paired-Simples T Test was used to determine differences in %MVIC of the Pilates exercises and the traditional squat. The level of significance was pre-set at $p \leq 0.05$.

RESULTS

There was no statistically significant difference in the amplitude of gluteus maximus muscle activation between the traditional squat and the Pilates exercises, including the superman ($t_{29} = 1.45$; $p = 0.159$), bird dog ($t_{29} = 1.38$; $p = 0.176$), and shoulder bridge ($t_{29} = 0.59$; $p = 0.563$) (Table 2).

DISCUSSION

This study aimed to compare the activation of the gluteus maximus during the execution of three Pilates method exercises and the traditional squat exercise. The hypothesis of this study was refuted, as the electromyographic activity of the gluteus maximus was similar in all four evaluated exercises.

Table 2. Electromyographic activation (%) of the gluteus maximus muscle during exercises.

Exercise	Gluteus Maximus MVIC (%)
Squat	84.35 ± 13.22
Superman	85.11 ± 11.66
Bird Dog	87.00 ± 10.76
Shoulder Bridge	83.44 ± 13.36

Mean ± standard deviation values.

The gluteus maximus muscle is the primary hip extensor, and its action is crucial for walking, running, jumping, and standing19. Although there are different bodyweight exercises for gluteus maximus activation, it has not yet been established which exercise activates this muscle better. Electromyography is a tool that allows obtaining information about the neuromuscular system through muscle activation amplitude data during exercise performance [20,21]. Thus, the present study aimed to compare the muscular activation of the gluteus maximus during Pilates exercises and squats. The search for more effective exercises to activate the gluteus maximus muscle is highly relevant for clinical practice due to the role this muscle plays in maintaining pelvic alignment, avoiding biomechanical compensations such as hip adduction and internal rotation during functional activities, which can lead to joint overload and favor the occurrence of injuries [22,23]. According to Silva et al [24], weakness of the gluteus maximus is considered a potential risk factor for musculoskeletal dysfunctions in the trunk and lower limbs, such as patellofemoral pain and low back pain [24]. Additionally, weakness in this muscle is associated with the intensity of patients' pain and the level of functional disability [24,25].

Contrary to the initial hypothesis, Pilates exercises were not superior for activating the gluteus maximus muscle. During the execution of the bridge exercise, unlike conventional squats, the knee is flexed throughout the hip thrust, making the hamstrings insufficiently active and thus requiring greater gluteus maximus muscle activation to generate efficient hip movement [19,26]. However, our results did not indicate these differences. Neto et al. [26] and Contreras et al. [27] found greater gluteus maximus muscle activation during the bridge exercise compared to squats [26,27]. This difference from our findings may be justified by the fact that the present study used body weight as resistance and did not use external resistance to perform the exercises, as done in the cited studies.

The bird dog exercise is one of the most popular exercises in Pilates [28]. Evidence suggests that the bird dog exercise primarily activates the extensors of the spine and hip [29,31]. Lehecka et al. [32] showed that the bird dog exercise exhibits moderate gluteus maximus activation, suggesting it to be an appropriate exercise for resistance training [32]. Losavio et al. [28] demonstrate that gluteus maximus activation is higher in dynamic bird dog exercise compared to bridge exercise [28]. The difference in our results compared to theirs may be justified by the variation in how the bird dog exercise was performed; in our study, it was performed in the quadruped position, whereas in the cited studies, it was performed standing. Reiman et al. [33] analyzed gluteus electromyographic activity in different exercises [33]. Unlike our study, they found that the bird dog exercise showed higher activation levels compared to pelvic elevation [33]. The difference in activation between the exercises was attributed to the fact that pelvic elevation requires a static condition to maintain neutral hip and spine positions during the exercise, and its low activation possibly reflected in the function of the gluteus maximus as a stabilizer of the hip and spine. The bird dog, on the other hand, demonstrated gluteus activity as both a stabilizer and extensor of the hip.

The superman exercise is performed in the prone position and requires a trunk extension movement along with hip extension during its execution. Kim et al. [29] and Dakfou et al. [34] showed that the superman exercise predominantly activates the lumbar muscles because lifting the upper and lower limbs off the ground increases spinal instability, thus activating the trunk stabilizers more to maintain spinal alignment [29,34]. Another factor that may have contributed to not finding greater gluteus maximus activation during the superman exercise is the limited extension range of motion, which was restricted to 20 degrees.

For greater efficiency in rehabilitation programs, it is crucial to understand which exercises can generate higher activation of a specific muscle [35]. In this regard, the present study investigated the main Pilates exercises used in clinical practice to strengthen the gluteus maximus and compared them with the activation provided during the traditional squat exercise. The findings of this study indicate that all four exercises exhibit similar gluteus maximus muscle activation and can be equally utilized in rehabilitation by healthcare professionals.

CONCLUSION

The gluteus maximus muscle activation proposed by the Pilates-based exercises was similar in magnitude to that observed during the squat exercise. These findings indicate that both types of exercises may be considered as options for promoting gluteus maximus activation in clinical settings. However, the results cannot be interpreted as evidence of muscle strengthening, since EMG amplitude does not necessarily reflect gains in strength.

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Citation: Minetto GM, Cipolli JR, Spinoso DH. (2025) Electromyographic activity of the gluteus maximus during exercises of the pilates method versus squat exercise. *Brazilian Journal of Motor Behavior*, 19(1):e489.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors
Competing interests: The authors have declared that no competing interests exist.
DOI: https://doi.org/10.20338/bjmb.v19i1.489