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Research article

Comparison of Muscle Activity in Three Single-Joint, Hip Extension Exercises in Resistance-Trained Women

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Abstract
The aim of the study was to compare neuromuscular activation in the gluteus maximus, the biceps femoris and the erector spinae from the Romanian deadlift, the 45-degree Roman chair back extension and the seated machine back extension. Fifteen resistance-trained females performed three repetitions with 6-RM loading in all exercises in a randomized and counterbalanced order. The activation in the whole movement as well as its lower and upper parts were analyzed. The results showed that the Romanian deadlift and the Roman chair back extension activated the gluteus maximus more than the seated machine back extension (94-140%, $p < 0.01$). For the biceps femoris the Roman chair elicited higher activation compared to both the Romanian deadlift and the seated machine back extension (71-174%). Further, the Romanian deadlift activated the biceps femoris more compared to the seated machine back extension (61%, $p < 0.01$). The analyses of the different parts of the movement showed that the Roman chair produced higher levels of activation in the upper part for both the gluteus maximus and the biceps femoris, compared to the other exercises. There were no differences in activation of the erector spinae between the three exercises ($p = 1.00$). In conclusion, both the Roman deadlift and the Roman chair back extension would be preferable to the seated machine back extension in regards to gluteus maximus activation. The Roman chair was superior in activating the biceps femoris compared to the two other exercises. All three exercises are appropriate selections for activating the lower back muscles. For overall lower limb activation, the Roman chair was the best exercise.

Key words: Gluteus maximus, biceps femoris, erector spinae, muscle activation.

Introduction

Strong hip and back extensors are considered important for sport-specific activity, daily tasks, and injury prevention (Contreras et al., 2016; Lariviere et al., 2010; Neto et al., 2020). Although several single-joint exercises are used to train the hip- and back extensors, little is known about the differences in how they activate the muscles. Single-joint hip extension exercise can be performed in several ways to target both the hip and the back extensors, typically using free weights (e.g. Romanian deadlift, Good mornings), machines (e.g. seated back extension), or a Roman chair. Although the movement is similar, these exercises are biomechanically different (Contreras et al., 2013). Contreras et al. (2013) compared the Good morning exercise, the 45-degree Roman chair back extension and the horizontal Roman chair back extension. The hip extension torque-pattern varied between the three exercises. The Good morning elicits the greatest torque in the lower part of the motion while the horizontal Roman chair exercise produces a peak in the upper part. In contrast, the 45-degree Roman chair back extension produces maximum torque in the middle of the motion. Importantly, in this exercise there is less change in the moment arm, creating a considerable amount of torque in both ends of the range of motion (338 Nm), resulting in less variation in torque. These differences in torque production would most likely affect muscle activation differently for both the whole movement, and the different parts of the movement. Alternatively, the seated back/hip extension machine transfers the load from the apparatus to the back through an upper back pad placed on the shoulder blades throughout the movement, keeping the moment arm and torque similar in all phases of the motion. However, performing the hip extension in a seated position with flexed knees and hip could be sub-optimal for activation of the different hip extensors (Kwon and Lee, 2013; Worrell et al., 2001).

Most studies examining the neuromuscular activation of the hip and back extensors have compared single-joint hip extensor exercises to either multi-joint exercises or knee flexor exercises (Delgado et al., 2019; Ebben, 2009; Lee et al., 2018; McAllister et al., 2014; McCurdy et al., 2018), but two of them also compared different single-joint, hip extensor exercises (Ebben, 2009; McAllister et al., 2014). McAllister et al. (2014) reported similar activation of the erector spinae, the biceps femoris and the gluteus medius in trained men performing 1 repetition at 85% of 1-RM in the Romanian deadlift and the Good morning exercise. Ebben et al. (2009) reported similar findings when they compared hamstring activation among athletes performing two repetitions, at 6-RM loading, in the Stiff-leg deadlift and the Good morning exercise. Common for both studies is the comparison of relatively similar biomechanical exercises, which could explain the lack of differences. To the authors' best knowledge, no previous study has compared neuromuscular activation in single-joint, hip extension exercises with different biomechanical properties (e.g. differences in moment arms).

The aim of the present study was to compare muscle activation in the gluteus maximus, biceps femoris and erector spinae from the Romanian deadlift, the 45-degree

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Roman chair back extension and the seated machine back extension. We hypothesized that the Roman chair exercise would have the highest gluteus and biceps femoris activation, especially in the upper part of the movement. Furthermore, we hypothesized that the Romanian deadlift would activate the same muscles more than the seated machine back extension.

Methods

Participants

Seventeen resistance trained females were recruited for the study, of which two dropped out during the familiarization period, leaving 15 complete cases (age 22 ± 1 years, body mass 69 ± 13 kg, stature 1.67 ± 0.07 m, resistance training experience 4 ± 2 years). The participants had to be over the age of 18, perform resistance training of the lower body on a weekly basis in the last year, be familiar with all three exercises and not have any injury or illness that prevented them from executing the exercises. The participants agreed to refrain from alcohol and resistance training of the lower-limbs 72 hours prior to the testing. They were informed orally and in writing about the procedures and had to provide a written consent before being enrolled in the study. The study was conducted in accordance to the University College`s ethical guidelines and all appropriate consent pursuant to the law was obtained before the start of the study.

Experimental design

A within-subjects, crossover design was used to compare the neuromuscular activation in the gluteus maximus, biceps femoris and the erector spinae between the Romanian deadlift, Roman chair back extension and the seated machine back extension. All electromyography (EMG) data were collected in one experimental session, to ensure identical electrode positioning throughout all conditions. The order of the exercises was randomized and counterbalanced. Before the experimental session, the participants performed a familiarization session and participated in a test session to determine 6RM in each exercise. In the experimental session, the participants performed three repetitions using the 6-RM load. Three to seven days separated each session.

Procedures

Familiarization

The first familiarization session was used to standardize the technique for each individual. Different measures (e.g. feet width, settings of the apparatus) were noted and kept identical at subsequent sessions. Three to seven days after the first familiarization the participants came back to the lab to determine the 6-RM in each exercise. The order of the exercises was randomized and counterbalanced, and kept identical throughout all three sessions for each individual.

The testing session included a general (five minutes of rowing) and specific warm-up. In the specific warm-up, participants performed six repetitions at 50% of 6-RM in the first set, six repetitions at 65% of 6-RM in the second set and three repetitions at 80% of 6-RM in the final set. Two minutes rest intervals were used between each set and self-reported 6-RM was used to determine loads during the warm-up. Following set three of the warm up, participants performed six repetitions with 6-RM load. If a true 6-RM was not determined in the first set, subsequent sets were performed with 3-5 minutes rest between. The load was adjusted by 2.5-5.0 kg between the attempts. For each exercise the 6-RM was obtained in 1-3 attempts.

Experimental session

The experimental session used the same warm-up as the 6-RM determination session, but with updated 6RM results. Following warm-up, three repetitions using the 6-RM loads were performed in each exercise. When changing exercise, participants performed a light adjustment set (3-5 repetitions at 40-50% of the 6-RM load). To avoid fatigue, a rest interval of four minutes was given between each attempt. The participants were instructed to perform all repetitions continuously and in a self-selected but controlled tempo. The difference in the hip angle range of motion, from upper to lower position, in all exercises were approximately 90 degrees. The angle in the two positions were controlled during the warm-up using a goniometer. A test leader gave oral feedback to the participants when they had reached the lower and upper positions in each exercise.

The Romanian deadlift (Figure 1A) was performed on a platform using an Olympic barbell (Eleiko, Halmstad, Sweden). The feet were shoulder width apart and the grip was slightly outside the legs. The participants started in an upright position and lowered themselves until the upper body was parallel to the floor (with a hip angle of approximately 90 degrees) before returning to the starting position. The knees were slightly bent throughout the movement. The back had to be straight with a natural sway.

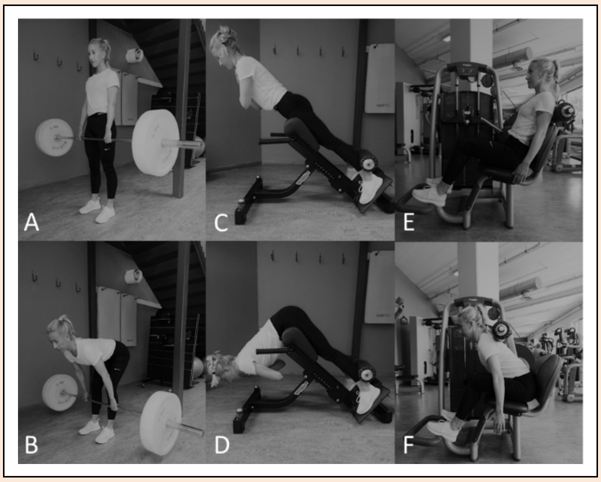

Figure 1. Upper and lower position of the Romanian deadlift (A and B), Roman chair back extension (C and D) and Seated machine back extension (E and F). Model: Helene Pedersen.

The Roman chair back extension (Figure 1B) was performed in a 45-degree Roman chair (Lower back bench PG05, Technogym, Cesena, Italy). External load was added via a weighted vest and plates held at the chest. The participants started in an upright position before lowering themselves down until the hip angle was approximately 90 degrees before returning to the starting position. The back had to be straight with a natural sway throughout the whole movement.

The seated machine back extension (Figure 1C) was performed in a Selection Line 700 Lower Back (Technogym, Cesena, Italy). The participants started in an upright and extended position before lowering the upper body until the hip angle had been reduced by approximately 90 degrees before returning to the starting position. The upper back pad was adjusted to align the scapulas. The arms had to be held alongside the body and the back had to be straight, with a natural sway throughout the whole movement. The use of the front or rear feet-support was optional, but the participants were encouraged to have approximately a 90 degree angle in the knee joint.

Electromyography

Before the experimental session, the skin on the side of the body of the dominant leg was prepared (shaved, abraded and washed with alcohol) in accordance with the guidelines of SENIAM (Hermens et al., 2000). Self-adhesive, gel-coated electrodes (Dri-Stick Silver circular sEMG Electrodes AE-131; Neuro-Dyne Medical Corp., Cambridge, MA, USA) were placed in the presumed direction of the underlying muscle fibers of the gluteus maximus, the biceps femoris and the erector spinae. The electrodes had an 11 mm contact diameter and a two cm center-to-center distance. To locate the positioning of the electrodes, the recommendations from seniam.org were used. For the gluteus maximus, the electrodes were placed half-way between the sacral vertebrae. For the biceps femoris, the electrodes were placed half-way between the ischial tuberosity and the lateral epicondyle of the tibia. Finally, the electrodes on the erector spinae were located at L1, 3 centimeters lateral to the spinous process and the greater trochanter.

The raw EMG signal was sampled at 1000 Hz. A fourth-order Butterworth filter was used to amplify and filter the signal (8-600 Hz), using a preamplifier located close to the sampling point (rejection ratio of 106dB). The EMG signals were the root mean square (RMS) converted using a hardware circuit network (frequency response 450 kHz, averaging constant 12 ms, total error ± 0.5%). The stored data was analyzed using a commercial software (MuscleLab 6000 system; Ergotest Technology AS, Langesund, Norway). The RMS of the mean EMG amplitude obtained from all three repetitions was used to calculate the activation for the whole movement. In addition, repetition number two and three were divided into upper and lower part, where each part consisted of half the ascending and half of the descending movement. The upper part was defined as the ascending movement from the mid-point of the lift until the top position and down to the mid-point again. The lower part consisted of the descending movement from the mid-point of the lift down to the lower position and back to the mid-point of the lift. The EMG for each part was defined as the mean of the corresponding movements. The parts were divided based on vertical displacement measured by a linear encoder (sampling frequency of 200 Hz, Ergotest Technology AS) which was synchronized with the EMG recording system MuscleLab 6000 system; Ergotest Technology AS). The encoder was also used to measure the lifting time in the three exercises.

To normalize the EMG data, the participants performed two maximal voluntary contractions (MVC). For the gluteus maximus, the participants lay in the prone position with a 90 degree angle in the knee joint. The dominant leg performed resisted hip extensor MVCs manually. For the biceps femoris, the participants, still lying in the prone position, performed knee flexor MVCs with a knee angle of approximately 45 degrees. For the erector spinae, resisted back extensor MVCs in the Biering–Sorenson position was performed (Zebis et al., 2013). The participants were instructed to obtain maximal force as quickly as possible and maintain it for 5-7 seconds (McBride et al., 2006). The highest average EMG amplitude over a 3-second window was used to normalize dynamic EMG data.

Statistical Analyses

Statistical analyses were performed with SPSS version 26 (SPSS, Inc., Chicago, IL, USA). Differences in neuromuscular activation and lifting time were assessed using one-way repeated measures ANOVA with Bonferroni post hoc tests. The different exercises (Romanian deadlift, Roman chair back extension and the seated machine back extension) were set as independent variables. All results are presented as mean and 95% confidence interval (95%CI) and Cohen`s d effect size (ES). An ES of 0.2 was considered small, 0.5 medium and 0.8 large (Cohen, 1988). Statistical difference was accepted at $p \leq 0.05$.

Results

The gluteus maximus

When analyzing the whole movement, the gluteus maximus was significantly more activated in the Romanian deadlift (94%, $p < 0.01$, ES = 1.85, table 1) and Roman chair back extension (140%, $p < 0.01$, ES = 2.15) when compared to the seated machine back extension. There were no differences between the Romanian deadlift and Roman chair back extension ($p = 0.151$, ES = 0.62). The same pattern was found in the lower part with the Romanian deadlift and Roman chair back extension being 100% ($p < 0.01$, ES = 1.91, Figure 2) and 110% ($p < 0.01$, ES = 1.61) more activated than seated machine back extension, with no differences between the two exercises ($p = 1.000$, ES = 0.17). In the upper part of the movement, the Roman chair back extension led to a higher activation than both the Romanian deadlift (74%, $p = 0.01$, ES = 1.13) and the seated machine back extension (207%, $p < 0.01$, ES = 2.18). Further, in the same phase the Romanian deadlift activated the gluteus maximus 77% more than the seated machine back extension ($p = 0.04$, ES = 0.91).

The biceps femoris

For the whole movement, the Roman chair back extension led to a higher activation of the biceps femoris compared to both the Romanian deadlift (71%, $p < 0.01$, ES = 1.04) and the seated machine back extension (174%, $p < 0.01$, ES = 1.70). Furthermore, the Romanian deadlift activated the biceps femoris more in comparison to the seated machine back extension (61%, $p < 0.01$, ES = 1.03). In the lower part of the movement, there was no difference between the Roman chair back extension and the Romanian deadlift ($p = 0.079$, ES = 0.57). However, both exercises demonstrated greater levels of activation compared to the seated machine back extension (Romanian deadlift; 73%, $p < 0.01$, ES = 1.10, Roman chair back extension; 121%, $p < 0.01$, ES = 1.58). In the upper part of the movement, the Roman chair back extension led to a higher activation compared to both the Romanian deadlift (124%, $p < 0.01$, ES = 1.68) and the seated machine back extension (222%, $p < 0.01$, ES = 2.18). The Romanian deadlift activated the biceps femoris 44% more than the seated machine back extension ($p < 0.01$, ES = 0.86).

The erector spinae

There were no differences in activation of the erector spinae between any of the exercises for the whole movement ($p = 1.000$, ES = 0.03 – 0.15), the upper part ($p = 1.000$, ES = 0.01 – 0.20) or the lower part ($p = 0.063 – 1.000$, ES = 0.02 – 0.70).

There were no significant differences in lifting time between any of the exercises ($p = 0.242 – 1.000$).

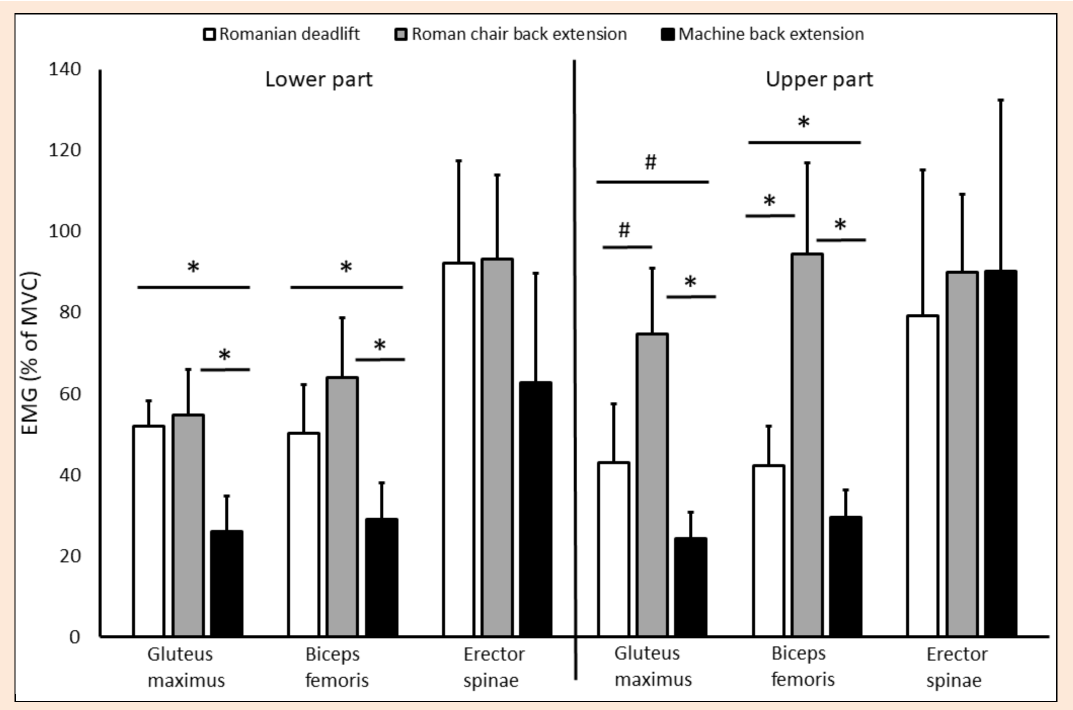

Figure 2. Normalized electromyographic (EMG) activation of the gluteus maximus, biceps femoris and erector spinae in the lower and upper part of the movement during Romanian deadlift, Roman chair back extension and Seated machine back extension. Values are means with 95% CI. * Significant difference ($p < 0.01$), # significant difference ($p < 0.05$).

Discussion

The main findings of the present study were that the Roman chair back extension activated the gluteus maximus and biceps femoris more than the two other exercises. Furthermore, the Romanian deadlift activated the same muscles more than the Seated machine back extension. There were no differences between the three exercises ability to activate the erector spinae.

As expected, the Roman chair back extension produced the highest levels of gluteus activation. However, compared to the Romanian deadlift, the difference only became statistically significant in the upper part of the movement. This is likely caused by biomechanical differences between the two exercises. The Romanian deadlift has a gradual decrease in the external torque from the lowest position, due to the reduction of the moment arm, with the torque close to zero in the top position. The Roman chair has a more consistent torque throughout the movement, with peak torque approximately in the middle of the movement (Contreras et al., 2013). Although not reaching statistical significance, there was a 23% difference in gluteus activation for the whole movement, between the two exercises. The difference had a moderate effect size (0.62). Further, both the Roman chair back extension and the Romanian deadlift activated the gluteus more than the seated machine back extension did, which resulted from differences in both the lower and upper part of the movement. A possible explanation could be the nature of the machine exercise. When seated in a machine, the hips are predominantly flexed throughout the movement. This has been demonstrated to reduce activation of gluteus muscles compared to when the hip is extended (Worrell et al., 2001). This observation could be related to different motor unit activation at different muscle length (Garland et al., 1994; Heckathorne and Childress, 1981), where the activation of the gluteus may be more optimal at shorter (i.e extended hip) compared to longer muscle length (i.e. flexed hip).

As mentioned, the Roman chair back extension, has a consistent external torque throughout the whole movement. This is most likely also the explanation for the Roman chair back extension showing the highest activation levels for the biceps femoris, which was in line with our hypothesis. The explanation is strengthened by the part-specific analyses, showing a clearer difference in the upper, compared to the lower part. As expected, the Seated machine back extension had the lowest biceps femoris activation of the three exercises. The biceps femoris is a bi-articular muscle with the ability to both flex the knee and extend the hip. When sitting in the back extension machine, the knees are flexed and some of the contraction of the biceps femoris is performed passively, likely reducing biceps femoris activation during the hip extension (Kwon and Lee, 2013). For the erector spinae, there were quite similar activations in erector spinae for the three exercises. This suggests that the lower back is exposed to a high torque in all three exercises which requires a high activation of the erector spinae.

Although this is the first study to compare muscle activation between these three exercises, some methodological limitations should be acknowledged. EMG is only an estimate of the neuromuscular activation and there will always be a risk of crosstalk from the neighboring muscles (Farina et al., 2004). Further, when measuring EMG during dynamic contractions there will always be a risk of electrode shift relative to the origin of muscle action potentials and changes in conductivity of the tissues separating muscle fibers and electrodes (Farina, 2006). However, these limitations should be reduced as all data were collected in one session without removing the electrodes. The different exercises were not performed to fatigue which could reduce the ecological validity towards training. However, performing the testing with sub-maximal intensity reduces the possibility of fatigue which also could affect the results. Also, as the relative intensity in the three exercises were identical (3 reps at 6-RM), the differences between the exercises shouldn`t be affected much by sub-maximal loading. The subjects in this study were all trained females and the findings can therefore not necessarily be generalized to other populations.

Conclusion

In conclusion, the Roman chair back extension activates the gluteus maximus and the biceps femoris more than Romanian deadlift and machine back extension. Further, the Romanian deadlift activated the same muscles more than the seated machine back extension. There were no differences concerning the activation of erector spinae between the three exercises.

The result of the present paper suggests that both the Romanian deadlift and the 45-degree Roman chair back extension are good single joint exercises for targeting the hip and back extensors. For athletes and recreationally active people aiming to optimize the neuromuscular activation of the glutes and hamstring, we would particularly recommend the Roman chair exercise. This exercise was in general more effective in activating these muscles, likely due to the biomechanical properties of the exercise creating a consistently large torque throughout the whole range of motion, and particularly in the upper part. It is also easier to perform with proper technique than the Romanian deadlift. Machine back extension was clearly inferior to the other two exercises.

However, if resistance training is performed to optimize specific parts of the movement, both the Roman chair exercise and the Romanian deadlift could have some advantages (Contreras et al., 2013). The Romanian deadlift maximizes its torque in a flexed hip position. As the hip is extended, the torque continuously decreases, allowing for increased velocity. These biomechanics would simulate running, and especially the top speed phase, where the hip torque is greatest in the late swing phase where the hip is flexed (Contreras et al., 2013). Therefore, we recommend athletes and recreational trained to consider the purpose of the exercises before choosing which one to include in their weekly resistance-training program.

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Key points

- In general, the Roman chair back extension lead to superior muscle activation compared to the Romanian deadlift and the seated machine back extension
- The seated machine back extension showed the lowest gluteus and hamstring activation
- All three exercises are appropriate selections for activating the lower back muscles
- The differences in muscle activation are most likely caused by biomechanical differences.

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