Electromyographic Comparison of Barbell Deadlift, Hex Bar Deadlift, and Hip Thrust Exercises: A Cross-Over Study

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Abstract

Andersen, V, Fimland, MS, Mo, D-A, Iversen, VM, Vederhus, T, Rockland Hellebø, LR, Nordaune, KI, and Saeterbakken, AH. Electromyographic comparison of barbell deadlift, hex bar deadlift, and hip thrust exercises: a cross-over study. *J Strength Cond Res* 32(3): 587–593, 2018—The aim of the study was to compare the muscle activation level of the gluteus maximus, biceps femoris, and erector spinae in the hip thrust, barbell deadlift, and hex bar deadlift; each of which are compound resisted hip extension exercises. After 2 familiarization sessions, 13 resistance-trained men performed a 1 repetition maximum in all 3 exercises in 1 session, in randomized and counterbalanced order. The whole ascending movement (concentric phase), as well as its lower and upper parts (whole movement divided in 2), were analyzed. The hip thrust induced greater activation of the gluteus maximus compared with the hex bar deadlift in the whole (16%, $p = 0.025$) and the upper part (26%, $p = 0.015$) of the movement. For the whole movement, the biceps femoris was more activated during barbell deadlift compared with both the hex bar deadlift (28%, $p < 0.001$) and hip thrust (20%, $p = 0.005$). In the lower part of the movement, the biceps femoris activation was, respectively, 48% and 26% higher for the barbell deadlift ($p < 0.001$) and hex bar deadlift ($p = 0.049$) compared with hip thrust. Biceps femoris activation in the upper part of the movement was 39% higher for the barbell deadlift compared with the hex bar deadlift ($p = 0.001$) and 34% higher for the hip thrust compared with the hex bar deadlift ($p = 0.002$). No differences were displayed for the erector spinae activation ($p = 0.312$–0.859). In conclusion, the barbell deadlift was clearly superior in activating the biceps femoris compared with the hex bar deadlift and hip thrust, whereas the hip thrust provided the highest gluteus maximus activation.

Key Words muscle activation, resistance training, gluteus maximus, biceps femoris, erector spinae

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32(3)/587–593

Journal of Strength and Conditioning Research

Introduction

Strong and powerful hip extensor muscles are essential for sport performance, activities of daily living, and injury prevention (9,18,19). Commonly used compound resisted hip extension exercises are the squat, deadlift, and hip thrust. Furthermore, to optimize the activation of specific muscles or for the purpose of variation in a periodized resistance training program, it is common to perform different variations of the same exercise (1–3). This can be done, for example, by moving the placement of the load horizontally (e.g., front squat vs back squat) relative to the axis of rotation (e.g., the hip joint). This would change the biomechanical demands of an exercise, altering the torque production around the active joints and thus probably influencing activation of the muscles involved. In line with this notion, a study by Yavuz et al. (21) observed higher quadriceps and lower hamstring activation for the front squat vs. back squat, although this pattern was not observed in 2 other studies (8,11).

It could be expected that horizontal movement of the load would also affect muscle activation in the deadlift. However, a kinematic analysis revealed that the squat and deadlift have quite different movement patterns (12); thus, findings from comparisons of squat variations cannot necessarily be inferred to seemingly similar deadlift comparisons. The hex bar deadlift is a variant of the barbell deadlift where one steps inside a hexagonally shaped bar. This allows for a more upright posture where the hip joint is closer to the trajectory line of the weights, reducing the resistive torque about the hip joint. Accordingly, Swinton et al. (20) reported lower peak moments in the lumbar spine for hex bar vs. barbell deadlift, and Camara et al. (4) observed that the barbell deadlift to a greater extent activated the biceps femoris and the erector spinae. However, these studies did not asses muscle activation of the prime hip extensor gluteus maximus muscle.

Recently, the barbell hip thrust has become a popular exercise for training the gluteus muscles. Unlike standing barbell exercises like the deadlift or squat, the tension on the hip extensors is at its greatest near lockout in the hip thrust (5). It could, therefore, be expected that the gluteus maximus would be more activated particularly in the end range of the movement in the hip thrust compared with the deadlift. In the only study comparing the hip thrust to standing hip extensor exercises, Contreras et al. (6) reported higher activation in the gluteus muscles and the biceps femoris compared with squats.

The aim of the study was to compare the muscle activation levels of the gluteus maximus, biceps femoris, and erector spinae during a 1 repetition maximum (1RM) in the hip thrust, barbell deadlift, and hex bar deadlift.

Methods

Experimental Approach to the Problem

A within-subject, cross-over design was used to compare the muscle activation levels in the gluteus maximus, biceps femoris, and erector spinae between the hip thrust, barbell deadlift, and hex bar deadlift, using 1RM loadings (Figure 1). To ensure identical positioning of the electrodes, all electromyography (EMG) data were collected in the same session. The testing order was randomized and counterbalanced. Two familiarization/strength testing sessions were performed before the experimental session; the first was used to practice the technique of the exercises, whereas 1RM tests were performed in the second.

Subjects

Thirteen healthy men aged 20–25 years old (mean ± *SD* age 21.9 ± 1.6 years, body mass 81.4 ± 7.2 kg, stature 180 ± 5.0 cm) with 4.5 ± 1.9 years of strength training experience volunteered for the study. Eligible participants had to be at least 18 years of age and familiar with the relevant exercises. They could not have an injury, disease, or pain that could reduce their maximal effort. The participants agreed to refrain from alcohol and resistance training of the legs in the 72 hours before each session. Participants were informed verbally and in writing about the procedures and provided written consent before they were included in the study. The study conformed to the latest revision of the Declaration of Helsinki. The study was also conducted in accordance to the ethical guidelines to the Sogn and Fjordane University College Review Board, and all appropriate written consent pursuant to law was obtained before the start of the study.

Procedures

The first familiarization test was used to optimize and standardize the technique for each individual. Relevant measurements (e.g., grip and feet width) were noted and

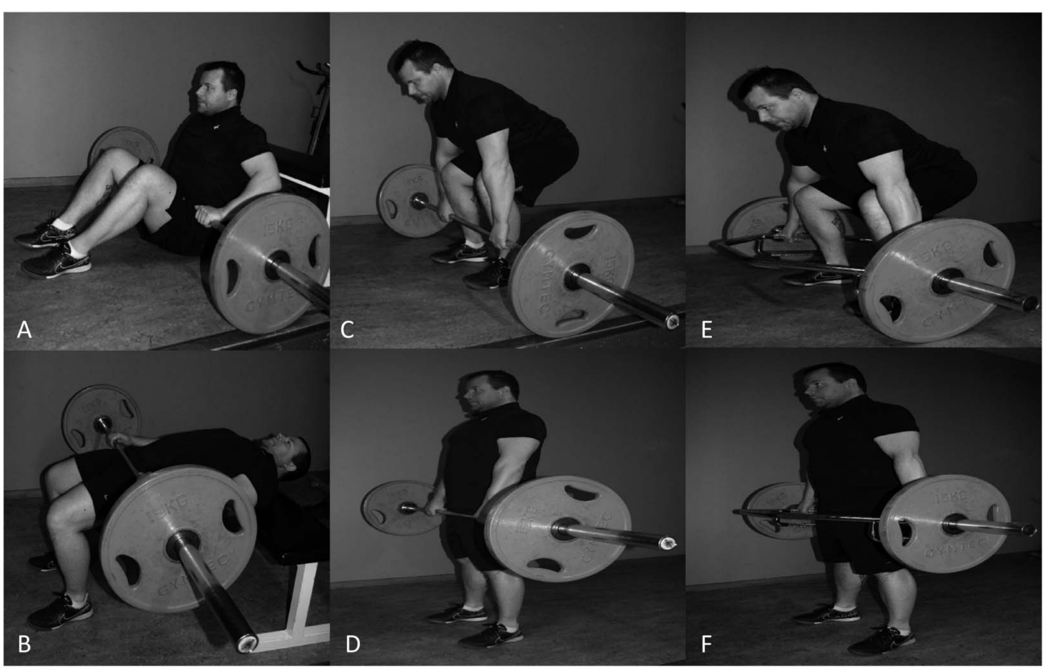

Figure 1. Lower and upper position in the hip thrust (A and B), barbell deadlift (C and D), and hex bar deadlift (E and F).

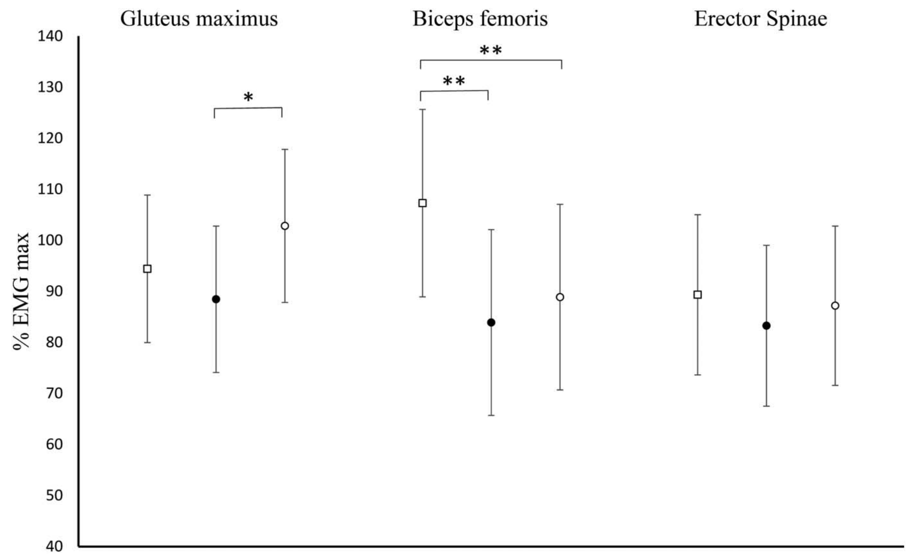

Figure 2. Mean electromyographic (EMG) activity (normalized to maximal voluntary isometric contraction) in the gluteus maximus, biceps femoris, and erector spinae during the barbell deadlift (□), hex bar deadlift (●), and hip thrust (○). Brackets indicate difference between exercise modalities (*$p \leq 0.05$, **$p < 0.01$). Values are mean with 95% confidence intervals.

used in the subsequent sessions. In the second session, 1RM was identified for the 3 exercises. The sessions were performed on nonconsecutive days.

The same warm-up was performed in the second familiarization and the experimental session; after 5 minutes on a treadmill or a bicycle, a specific progressive warm-up in the barbell deadlift was performed: 12 repetitions at 30% of 1RM, 10 repetitions at 50% of 1RM, 8 repetitions at 70% of 1RM, and 2 repetitions at 90% of 1RM. The self-reported 1RM was used to calculate the warm-up loads in the second familiarization session, whereas the 1RM result achieved in the second familiarization test was used to decide loadings in the experimental session. A rest interval of 3–5 minutes was given between each lift.

During the experimental session, the 1RM obtained in the second familiarization test was used. When necessary, the load was increased or decreased by 2.5 kg or 5 kg until 1RM was achieved (1–3 attempts). One familiarization set consisting of 4–6 repetitions with a submaximal load was performed to adjust to the movement pattern of a new exercise. The testing was terminated when a lift could not be completed with a proper technique (described below). Lifting straps were allowed during deadlifts.

All tests were performed on a lifting platform using an Olympic barbell (barbell deadlift and hip thrust), a hex bar, and weight plates (Eleiko, Halmstad, Sweden). The width between and the rotation of the feet were identical in all 3 exercises. To match the handle width on the hex bar (Figure 1), a 72-cm grip width in the barbell deadlift was used. In the deadlift variations, the lift started with the weights resting on the platform. The participants were instructed to lift the barbell while maintaining a neutral, straight back and to extend their knees and hip in 1 movement (to avoid a straight-leg deadlift technique). The lift was completed when the hip was fully extended (the angle between the trunk and the thigh was approximately 180°). The main difference between the 2 variations of deadlift was the placement of the load relative to the axis of rotation (i.e., the hip joint). For the barbell deadlift, the barbell was lifted in front of the participant (Figure 1), whereas for the hex bar deadlift, participants stood "inside" the hex bar with the arms alongside the legs with a more upright posture (Figure 1). Hence, the lever arm from the hip joint to the weight is longer during most of the lift for the barbell deadlift. In the hip thrust, the participants started in a seated position on the ground with their upper back leaning toward a bench (height: 49 cm). The barbell was placed at the crease of the hips slightly above the pelvis (5), before thrusting the barbell up until the hip was fully extended while maintaining a neutral, straight back. The angle of the knees was approximately 90° in the upper position. The participants were not instructed to lower the weights in a controlled manner, allowing them to drop the weights from the extended position.

Electromyography. Before placing the gel-coated self-adhesive electrodes (Dri-Stick Silver circular sEMG Electrodes AE-131; Neuro-Dyne Medical Corp., Cambridge, MA, USA), the skin was shaved, abraded, and washed with alcohol. The electrodes (11 mm contact diameter and a 2-cm center-to-center distance) were placed in the presumed direction of the underlying

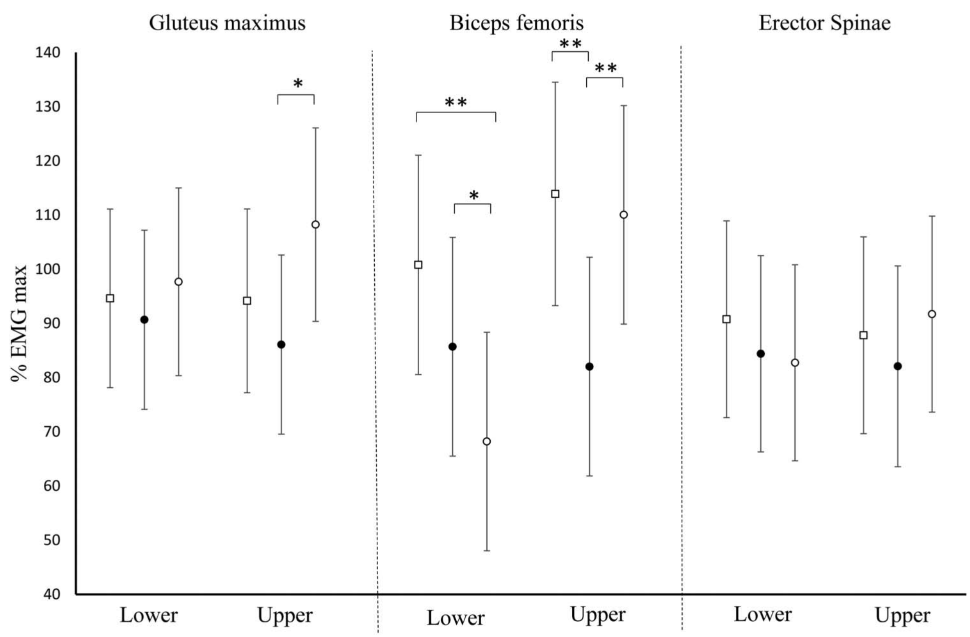

Figure 3. Mean electromyographic (EMG) activity (normalized to maximal voluntary isometric contraction) in the lower and upper phase of the movement in the gluteus maximus, biceps femoris, and erector spinae during the barbell deadlift (□), hex bar deadlift (●), and hip thrust (○). Brackets indicate difference between exercise modalities (*$p \leq 0.05$, **$p < 0.01$) in the relevant phase. Values are mean with 95% confidence intervals.

muscle fibers on gluteus maximus, biceps femoris, and erector spinae according to the recommendations by SENIAM (13), on the side of the dominant leg. For the gluteus maximus, the electrodes were placed half-way between the sacral vertebrae and the greater trochanter. 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 (13).

To minimize noise from the surroundings, the raw EMG signal was amplified and filtered using a preamplifier located close to the sampling point. The preamplifier had a common mode rejection ratio of 100 dB, high-cut frequency of 600 Hz, and low-cut frequency of 8 Hz. The EMG signals were converted to root mean square (RMS) signals using a hardware circuit network (frequency response 0–600 kHz, averaging constant 100 ms, total error ±0.5%). Finally, the RMS converted signal was sampled at 100 Hz using a 16-bit A/D converter. Commercial software (MuscleLab V8.13; Ergotest technology AS, Langesund, Norway) was used to analyze the stored EMG data. The RMS of the mean EMG amplitude obtained during the ascending movement of the lift was calculated. In addition, the lift was divided into the upper and lower phase of the ascending movement (vertical displacement divided in 2). A linear encoder attached to the barbell identified the beginning and end of the lift, the different phases, and the lifting time (Ergotest Technology AS, Langesund Norway, sampling frequency of 100 Hz). The linear encoder was synchronized with the EMG recording system (MuscleLab 4020e; Ergotest Technology AS, Langesund, Norway). After recording dynamic EMG data, 2 maximal voluntary isometric contractions (MVCs) for all 3 muscles were measured. For the gluteus maximus, the participants lay in the prone position while the legs were straight. 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°. For the erector spinae, resisted back extensor MVCs in the Biering–Sorenson position was performed (22). The participants were instructed to obtain maximal force as quickly as possible and maintain it for at least 3 seconds (16,17). The MVC with the greatest average EMG amplitude over a 3-second window was used to normalize dynamic EMG data.

Statistical Analyses

Mixed-effects linear regression models were used to compare overall and phase-dependent muscle activation levels between the exercises (barbell deadlift, hex bar deadlift, and hip thrust) for each muscle (gluteus maximus, biceps femoris, and erector spinae). Normalized EMG was the dependent variable in the model, whereas exercise and phase of the movement (lower and upper), as well as their interaction term, were included as fixed effects. We also included a random intercept for participant identity (allowing participants to start out at different levels). Lifting time, subject height, and years of training experience were treated as potential confounders and added to the model using a forward approach. Variables were considered confounders if they induced >10% change in the regression coefficients. p-values (2-tailed) <0.05 were considered statistically significant, whereas 95% confidence intervals were used to assess the precision of the estimates. For all models, the regression residuals were visually inspected regarding normality of distribution (qq-plots and histogram). Statistical analyses were performed in STATA/IC 13.1 for windows (StataCorp LP, College Station, TX, USA).

Results

All regression residuals appeared to be normally distributed with qq-plots, but histograms displayed nonnormality for some of the random effect residuals. Thus, all analyses were performed using both nontransformed and log-transformed variables. As the results did not differ, the final analyses were performed with nontransformed variables. Lifting time was identified as a confounder and adjusted for in the analyses.

For the whole ascending movement, the gluteus maximus activation was 16% higher in the hip thrust compared with the hex bar deadlift ($p = 0.025$, Figure 2). Furthermore, the biceps femoris activation was 28% higher in the barbell deadlift compared with the hex bar deadlift ($p < 0.001$) and 20% higher in the barbell deadlift compared with the hip thrust ($p = 0.005$). No significant differences were displayed for erector spinae activations ($p = 0.375$–0.750).

The gluteus maximus activation was 26% higher in the upper part of the movement during the hip thrust compared with the hex bar deadlift ($p = 0.015$, Figure 3). The biceps femoris activation was higher in the lower part of the movement for the barbell deadlift compared with the hip thrust (48%, $p < 0.001$) and for the hex bar deadlift compared with the hip thrust (26%, $p = 0.049$). Furthermore, the biceps femoris activation in the upper part of the movement was 39% higher for the barbell deadlift compared with the hex bar deadlift ($p = 0.001$) and 34% higher for the hip thrust compared with the hex bar deadlift ($p = 0.002$). No significant differences were displayed for erector spinae activations ($p = 0.312$–0.859).

The 1RM in the hip thrust (176.6 ± 32.4 kg) was higher than that for both the barbell (150.6 ± 24.2 kg, $p = 0.001$) and the hex bar deadlift (153.5 ± 22.4 kg, $p < 0.001$). There were similar lifting times for the exercises: barbell deadlift: 2.28 ± 0.91 seconds, hex bar deadlift: 1.98 ± 0.59 seconds, hip thrust: 2.02 ± 0.55 seconds.

Discussion

The main results of the study were that for the whole movement: (a) the hip thrust induced higher activation of the gluteus maximus compared with the hex bar deadlift, (b) the barbell deadlift provided higher activation of the biceps femoris vs. the hex bar and hip thrust, and (c) all exercises had similar erector spinae activations.

The hip thrust induced higher EMG activity in the gluteus maximus than the hex bar deadlift in the whole and particularly during the upper phase of the movement. Similarly, Contreras et al. (6) reported higher activation of the gluteus maximus when they compared the hip thrust with the back squat, which despite being a different exercise is relatively similar to the hex bar deadlift. These findings are probably due to the higher tension on the hip extensors in the hip thrust vs. the hex bar deadlift and back squat exercises, in the end range of the movement (5). However, we did not observe a significant difference in the gluteus maximus activation between the hip thrust and barbell deadlift, although there was an 8 and 13% difference in the mean EMG activity of the whole and upper part of the movement, respectively, in favor of the hip thrust.

According to a biomechanical analysis, the barbell deadlift stresses the hip more than the hex bar deadlift because the bar is lifted in front of the legs and the back acts as a longer lever arm (20). However, we observed similar gluteus maximus activation levels for the 2 deadlift variants. This finding is in line with 2 previous studies on the front vs. back squat (8,21) which is analogous to our comparison of barbell deadlift and the hex bar deadlift because both vary the positioning of the load horizontally relative to the hip joint. Nonetheless, the biceps femoris, which also acts as a hip extensor, was more activated by the barbell deadlift than the hex bar and hip thrust.

That the barbell deadlift provided higher biceps femoris activation than the hip thrust in the whole movement was due to the substantial difference between the 2 in the first half of the movement. In the start of the lift during the barbell deadlift, the lever arm from the hip joint to the load is at its longest, creating a lot of stress on the hip extensor muscles. Conversely, in the hip thrust, the active muscle force in the gluteus maximus and hamstrings is higher toward the end of the movement than in the start. Another possible explanation could be the initial muscle length. In the barbell deadlift, the knees are more extended in the beginning of the movement compared with the hip thrust, and therefore increasing the muscles' ability to generate force (14).

The barbell deadlift also produced greater biceps femoris activation than the hex bar deadlift. This finding is in accordance with Camara et al. (4) who compared muscle activity in the barbell deadlift and hex bar deadlift with submaximal loading among resistance-trained men. They found a 15% higher activation of the biceps femoris during the concentric movement. One reason could be the increased lever arm, and therefore higher torque created around the hip (20). Another could be that the role of the biceps femoris as a hip extensor is greater when the knees are close to fully extended (12). However, although activations were higher in both phases for the barbell deadlift, the difference only reached statistical significance for the upper phase.

For the whole movement, there were no difference in the biceps femoris activation between the hip thrust and the hex bar deadlift. However, analyzing the different phases showed opposite results, as the hex bar deadlift induced higher EMG in the lower phase, whereas the hip thrust elicited greater EMG in the upper phase. In the upper phase, the muscle activation was substantially increased for the hip thrust, probably due to the increased hip torque requirement in the end range of this horizontally loaded exercise, whereas it slightly declined for the hex bar deadlift. Although not entirely comparable, Contreras et al. (6) found higher biceps femoris activation in the whole movement phase of the hip thrust vs. back squat.

We found similarly high activation levels of the erector spinae for all exercises. Our finding was supported by Camara et al. (4) who found no differences for the erector spinae between the barbell and the hex bar deadlift. Furthermore, neither Gullett et al. (11) nor Yavuz et al. (21) found any differences in the erector spinae activation when they compared the front and the back squat. Therefore, it seems that the horizontal positioning of the load relative to the hip does not influence erector spinae EMG amplitude much.

This study has some limitations. Only resistance-trained men were recruited and the results can, therefore, not necessarily be generalized to other populations. In addition, maximal loading was used in all tests, and it is possible that the relative contribution from the muscles involved would have differed with submaximal loadings. Furthermore, the optimal bench height for the hip thrust has not been determined. The bench used was 49 cm high, which may have been suboptimal for some or all of our participants. Furthermore, some type II errors might have occurred as only 13 participants were recruited, limiting the statistical power of the study. In addition, we intended to also include the quadriceps muscles; however, several participants were not able to use their preferred technique without scraping the barbell against the electrodes in the barbell deadlift with 1RM loading, thus the quadriceps EMG recordings were omitted. The MVC for the gluteus maximus was performed with a straight-leg hip extension instead of the prone bent leg extension which could have provided higher EMG activation (7,8). However, this would not change the results of the comparisons between the exercises in the study. Moreover, surface EMG gives only an estimate of the neuromuscular activation, and there will always be a possible risk of crosstalk from surrounding muscles (10). The EMG data were also collected during dynamic contractions which have more potential sources for error than isometric contractions (10). Importantly, all EMG data were collected in the same session which substantially reduces the potential for error (15).

In conclusion, the barbell deadlift was clearly superior in activating the biceps femoris compared with the hex bar deadlift and hip thrust, whereas the hip thrust provided the highest gluteus maximus activation. There were no differences between the exercises for the erector spinae activation.

Practical Applications

Appropriate exercise selection is important when designing resistance training programs. During a lift with maximum loading, the hip thrust was the exercise that provided the highest muscle activation for the gluteus maximus, particularly in the upper phase of the movement where standing exercises have decreased tension on the hip extensors. The barbell deadlift was clearly more effective in activating the biceps femoris than the hip thrust and hex bar deadlift. The hex bar deadlift generally provided the lowest muscle activation for these muscles. For optimal hip extensor strength development, we therefore recommend including both the hip thrust and barbell deadlift exercises.

Acknowledgments

The authors thank the participants for their positivity and participation in the study. This study was conducted without any funding from companies or manufacturers or outside organizations.

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