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A Comparison of Gluteus Maximus, Biceps Femoris, and Vastus Lateralis Electromyography Amplitude for the Barbell, Band, and American Hip Thrust Variations

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Bridging exercise variations are well researched and commonly employed for both rehabilitation and sport performance. However, resisted bridge exercise variations have not yet been compared in a controlled experimental study. Therefore, the purpose of this study was to compare the differences in upper and lower gluteus maximus, biceps femoris, and vastus lateralis electromyography (EMG) amplitude for the barbell, band, and American hip thrust variations. Thirteen healthy female subjects (age = 28.9 y; height = 164.3 cm; body mass = 58.2 kg) familiar with the hip thrust performed 10 repetitions of their 10-repetition maximum of each variation in a counterbalanced and randomized order. The barbell hip thrust variation elicited statistically greater mean gluteus maximus EMG amplitude than the American and band hip thrusts, and statistically greater peak gluteus maximus EMG amplitude than the band hip thrust ($P \leq .05$), but no other statistical differences were observed. It is recommended that resisted bridging exercise be prescribed according to the individual's preferences and desired outcomes.

Keywords: bridging exercise, resistance training, hip extension, lower extremity, electromyography

Bridging exercise variations are commonly employed for both rehabilitation[1–3] and enhancement of sport performance.[4–6] For such purposes, both bodyweight and loaded bridging exercise variations are performed. Consequently, bodyweight bridging exercises have frequently been compared with one another in the literature. For example, unilateral bridges have been shown to elicit about double the upper gluteus maximus electromyography (EMG) amplitude than bilateral bodyweight bridges.[7] However, despite their popularity for strength and conditioning, no loaded bridges have been compared. Barbell exercises are a staple in strength and conditioning programs around the world, and typically outperform machine exercises in muscle activation.[8,9] The barbell hip thrust, introduced in the literature by Contreras and colleauges,[10] is a loaded bridging exercise used to target the hip extensor musculature against barbell resistance. It has recently been suggested that the barbell hip thrust can enhance speed, horizontal force production, and gluteus maximus hypertrophy.[10–13] Moreover, recent work from our laboratory found that the barbell hip thrust elicited superior gluteus maximus and biceps femoris EMG amplitude in comparison with the barbell back squat.[14] This may be because the barbell allows the lifter to maintain a more consistent hip extension moment requisite throughout the entire range of motion.

In sports science research, exercises are commonly compared with one another to help determine which exercise leads to more favorable changes in variables of interest. For example, muscle activation is often compared between exercises.[15–24] To the authors' knowledge, no study to date has examined bridging variations that use external resistance, nor has any study to date compared one variation versus another.

The American hip thrust is similar to the barbell hip thrust but involves posterior pelvic tilt (PPT), which mimics hip extension.[25] Research has shown that PPT can enhance gluteus maximus activation,[26,27] as our group has previously shown in the plank.[28] It is therefore plausible that combining PPT with hip extension during the hip thrust will promote greater gluteus maximus activation. However, performing PPT during the hip thrust seems to involve a greater degree of neuromuscular coordination, which some lifters have trouble mastering.

Bands have recently been shown to elicit similar levels of EMG amplitude compared with free weights,[29,30] and to alter the moment-angle curve to require greater hip extension moments at shorter muscle lengths.[31,32] Because the gluteus maximus elicits the greatest amount of EMG amplitude at end-range hip extension,[33] it is plausible that the band hip thrust might outperform the barbell in peak gluteus maximus EMG. However, since bands fail to maintain consistent levels of resistance throughout the movement, some of the exercise range of motion is lacking in adequate resistance.

The gluteus maximus muscle appears to be segmented into at least 2 subdivisions, which may display different EMG amplitude in response to certain muscle actions. McAndrew and colleagues[34] used a laser-based mechanomyographic (MMG) technique to measure the mean contraction time in 6 subdivisions of the gluteus

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maximus, both in the sagittal plane (superior, middle, inferior) and in the frontal plane (medial and lateral). The superior region displayed the longest contraction time, followed by the middle region and then the inferior region. On the basis of these findings, McAndrew and colleagues[34] suggested that the superior region may contain more slow-twitch fibers and be more involved in postural tasks compared with the inferior region, while the inferior region may contain more fast-twitch fibers and be more involved in dynamic tasks. This is further substantiated by the work of Lyons and colleagues[35] and Karlsson and Jonsson,[36] who found differences between upper and lower gluteus maximus EMG during functional movement; for example, load acceptance during stair ambulation better targets the lower gluteus maximus,[35] while hip abduction better targets the upper gluteus maximus.[36] Therefore, it is plausible that the upper and lower gluteus maximus experience differential activation patterns between different exercise variations.

The purpose of this investigation was to compare the EMG amplitude of the upper gluteus maximus, lower gluteus maximus, biceps femoris, and vastus lateralis during the barbell, band, and American hip thrust variations. It was hypothesized that barbell hip thrust would elicit greater upper gluteus maximus, lower gluteus maximus, biceps femoris, and vastus lateralis EMG amplitude than the band and American hip thrusts.

Methods

To help close the gender gap in exercise science and sports medicine research,[37] a homogenous sample of 13 healthy females participated in this study. Subjects (age = 28.9 ± 5.1 y; height = 164.3 ± 6.3 cm; body mass = 58.2 ± 6.4 kg) had 7.0 ± 5.8 years of resistance training experience and had a 10-repetition maximum (10RM) of 87.4 ± 19.3 kg in the barbell hip thrust. Inclusion criteria required subjects to be between 20 and 40 years of age, have at least 3 years of consistent resistance training experience training at least 3 times per week, and be familiar with performance of the hip thrust exercise. All subjects were healthy and denied the existence of any current musculoskeletal or neuromuscular injuries, pain, or illnesses. Subjects filled out an informed consent form and the Physical Activity Readiness Questionnaire (PAR-Q). Any subject that answered “Yes” to any of the questions on the PAR-Q was excluded from the study. Subjects were advised to refrain from training their lower body for 72 hours before testing. To ensure acceptable performance in the barbell hip thrust, subjects performed each movement using only a barbell while the lead researcher evaluated technique. If a subject reported pain, discomfort, or failed to perform the movement correctly, she was excluded from participation. If, for any reason, a subject could not complete a trial, her data were discarded. The study was approved by the Auckland University of Technology Ethics Committee.

Subjects first performed a 10-minute general warm-up consisting of various dynamic stretches for the lower body musculature. Afterward, 3 progressively heavier specific warm-up sets were performed for the hip thrust exercise. Next, subjects’ 10RM in barbell, band, and American hip thrusts were calculated using the methods described by Baechle and Earle,[38] by performing as many repetitions with what each subject perceived to be a moderately heavy load. Order of the testing was randomized.

Subjects were asked to wear appropriate clothing for access to the EMG electrode placement sites. Before placing the electrodes on the skin, excess hair was removed with a razor, and skin was cleaned and abraded using an alcohol swab. After preparation, self-adhesive disposable silver/silver chloride pregelled dual-snap surface bipolar electrodes (Noraxon Product #272, Noraxon USA Inc., Scottsdale, AZ) with a diameter of 1 cm and an interelectrode distance of 2 cm were attached in parallel to the fibers of the right upper gluteus maximus, lower gluteus maximus, biceps femoris, and vastus lateralis in concordance with the recommendations of Hermens and colleagues[39] and Lyons and colleagues.[35] After the electrodes were secured, a quality check was performed to ensure EMG signal validity.

Ten minutes after 10RM testing, maximum voluntary isometric contraction (MVIC) testing was performed. For the gluteus maximus, 2 MVIC positions were tested. The first involved a prone bent-leg hip extension against manual resistance applied to the distal thigh, as used by Boren and colleagues,[40] and the second involved a standing glute squeeze. Pilot data from our laboratory revealed that a minority of subjects achieved higher levels of gluteus maximus EMG amplitude with the standing glute squeeze than during the prone bent-leg hip extension against manual resistance; thus, both conditions were recorded and EMG was normalized to whichever contraction elicited greater EMG amplitude.[41] Biceps femoris MVIC was determined by having the subject lay prone and produce maximum knee flexion moment at 45° knee flexion against manual resistance applied to the distal leg just above the ankle, as found to be superior by Mohamed and colleagues.[42] Two vastus lateralis MVIC positions were used. The first had the subject sit and produce a maximum knee extension moment against manual resistance applied to the distal leg just above the ankle at 90° hip flexion and 90° knee flexion, as found to be superior by Kong and Van Haselen,[43] while the second used a 90° hip flexion and 180° knee position. Whichever contraction elicited greater EMG amplitude was used for normalization. In all MVIC positions, subjects were instructed to contract the tested muscle “as hard as possible.” These methods are identical to those used by Contreras and colleagues.[14,44]

After 10 minutes of rest following MVIC testing, subjects performed 10 repetitions utilizing their estimated 10RM of the barbell, band, and American hip thrusts in a counterbalanced, randomized order. In accordance with Contreras and colleagues,[10] the barbell hip thrust was performed with the subjects’ backs on a bench, approximately 16 inches high. The subjects’ feet were slightly wider than shoulder-width apart, with toes pointed forward or slightly outward. The barbell was padded with a thick bar pad and placed over the subjects’ hips. The subjects were instructed to thrust the bar upwards while maintaining a neutral spine and pelvis (Figure 1). A full range of motion was used for each repetition, beginning with the bar touching the ground and ending in full hip extension. The American hip thrust was performed in a similar fashion but the subjects were positioned on the bench such that the inferior angle of the scapulae rested on the bench. Subjects combined hip extension and posterior pelvic tilt in this variation, which required a blend of anterior pelvic tilt and hip flexion during the eccentric portion of the movement and posterior pelvic tilt and hip extension during the concentric portion of the movement (Figure 2). The band hip thrust was performed identically to the barbell hip thrust but with elastic resistance bands instead of a barbell (Figure 3). In each variation, hip range of motion was kept consistent, which required that subjects reverse the movement in midair with the American hip thrust, since the bar does not touch the ground during this variation. Subjects were given 5 minutes of rest between sets. No predetermined tempo was set so as to better represent true training conditions.

Raw EMG signals were collected at 2000 Hz by a Myotrace 400 EMG unit (Noraxon USA Inc, Scottsdale, AZ). Data were sent in real time to a computer via Bluetooth and recorded and analyzed by MyoResearch 3.6 Clinical Applications software (Noraxon USA, Inc., Scottsdale, AZ). Signals of all 10 repetitions for the dynamic

Figure 1 — Barbell hip thrust technique.

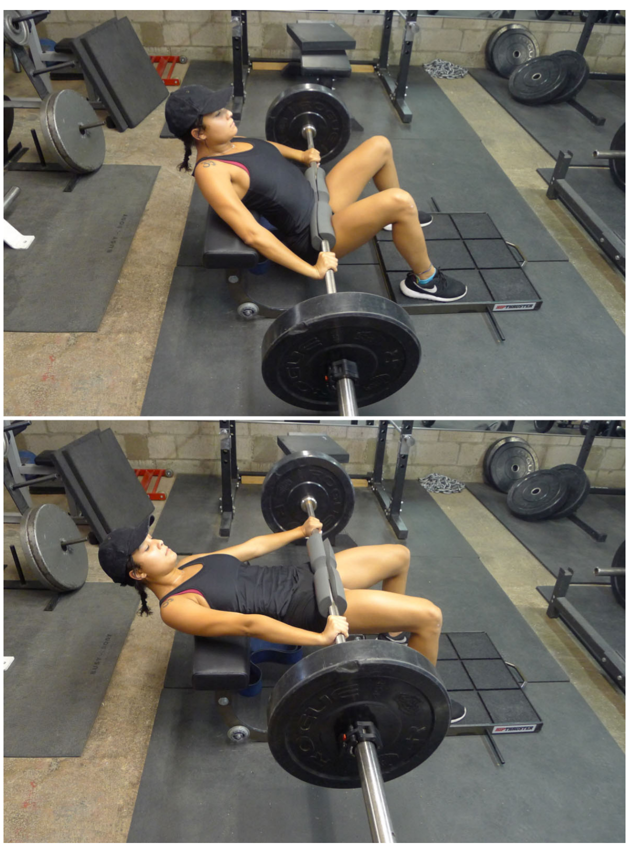

Figure 2 — American hip thrust technique.

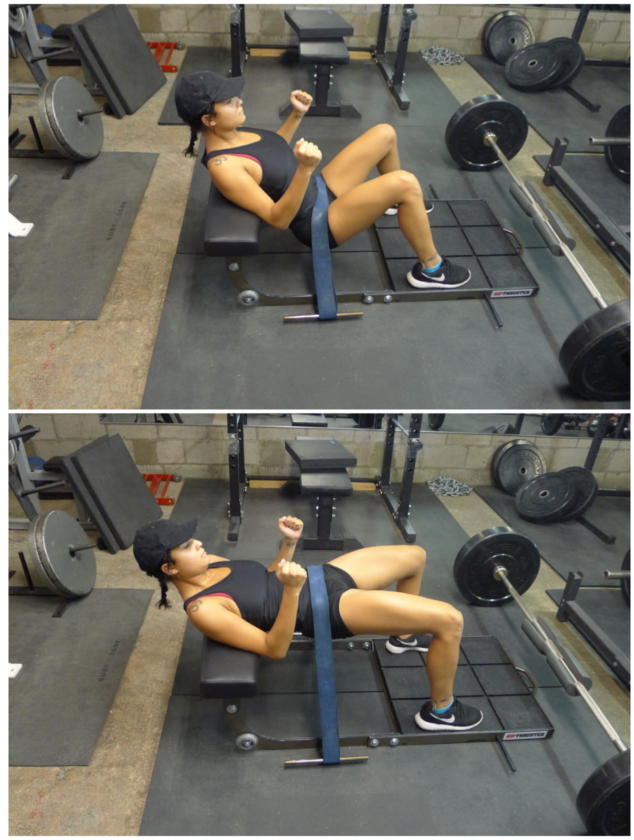

Figure 3 — Band hip thrust technique.

sets and for all 3 seconds of the isoholds were rectified and smoothed with a root mean square (RMS) algorithm with a 100-millisecond window. Mean and peak data were normalized to a mean peak of a 1000-millisecond window from the MVIC trials; that is, the 1000-millisecond window with the greatest mean EMG amplitude.

Sphericity (Mauchly test) and normality (Shapiro-Wilk test) were checked before performing one-way analyses of variance (ANOVA) with repeated measures (parametric) or the Friedman test (nonparametric) to investigate if within-subject, within-muscle differences existed between hip thrust variations. If data were parametric but did not meet sphericity assumptions, Greenhouse-Geisser corrections to degrees of freedom were applied. For parametric data in which a main effect was observed, paired samples *t* tests were performed. Nonparametric data in which main effects were found were compared using Wilcoxon paired-samples signed-rank tests. Alpha was set to .05 and a Bonferroni correction was applied to post hoc pairwise comparisons. Bonferroni-corrected *p*-values are presented in these cases. Parametric effect sizes (ES) were calculated by Cohen's *d* using the formula

$$d = \frac{M_d}{s_d}$$

where M_d is mean difference and s_d is the standard deviation of differences.[45–47] This method is slightly different than the traditional method of calculating Cohen's *d*, as it calculates the within-subject ES rather than group or between-subject ES. Cohen's *d* was defined as small, medium, and large for 0.20, 0.50, and 0.80, respectively.[48] Nonparametric ES were reported in terms of Pearson's *r*:

$$r = \frac{z}{\sqrt{n}}$$

Pearson's *r* was defined as small, medium, and large for 0.10, 0.30, and 0.50, respectively.[48] Additionally, 95% confidence intervals (CI) of ES from the pairwise comparisons were calculated and presented.

Results

The 10RM of the American hip thrust used was 91.9 ± 18.5 kg, and the 10RM of the barbell hip thrust used was 87.4 ± 19.3 kg.

The Friedman test revealed statistical differences between mean upper gluteus maximus EMG amplitudes ($X^2[2] = 12.462$; $P = .002$). Bonferroni-corrected post hoc pairwise comparisons revealed that the barbell hip thrust elicited statistically greater mean upper gluteus maximus EMG amplitude than the American (t[12] = 3.016; $P = .032$; Cohen's $d = 0.84$ [0.23, 1.44]) and band (t[12] = 3.446; $P = .014$; Cohen's $d = 0.96$ [0.35, 1.56]) hip thrust variations; no statistical differences were found between the American and band hip thrust variations (t[12] = 2.159; $P = .155$; Cohen's $d = 0.60$ [–0.01, 1.20]). No statistical differences between conditions were found to be present for mean lower gluteus maximus (F[2,24] = 0.739; $P = .488$; $\eta^2 = 0.024$), biceps femoris (F[1.289, 15.474] = 0.760; $P = .429$; $\eta^2 = 0.024$), or vastus lateralis ($X^2[2] = 2.627$; $P = .269$) EMG amplitude (Table 1). The number of subjects that achieved the greatest mean EMG amplitude in each variation is shown in Table 2.

The Friedman test revealed statistical differences between peak upper gluteus maximus EMG amplitudes ($X^2[2] = 10.308$; $P = .006$). Bonferroni-corrected post hoc pairwise comparisons revealed that the barbell hip thrust elicited statistically greater upper gluteus maximus EMG amplitude than the band hip thrust variation (t[12] = 2.892; $P = .041$; Cohen's $d = 0.80$ [0.020, 1.41]); no statistical differences were found between barbell and American hip thrusts (t[12] = 1.600; $P = .407$; Cohen's $d = 0.44$ [–0.16; 1.05]) or American and band hip thrusts ($z = 1.363$; $P = .519$; Pearson's $r = .38$ [–0.22, 0.77]). No statistical differences between conditions were found to be present for peak lower gluteus maximus ($X^2[2] = 2.000$; $P = .368$), biceps femoris (F[1.380, 16.561] = 0.585; $P = .508$; $\eta^2 = 0.016$), or vastus lateralis ($X^2[2] = 2.471$; $P = .291$) EMG amplitude (Table 1). The number of subjects that achieved the greatest peak EMG amplitude in each variation is shown in Table 2.

Table 1 EMG (%MVIC) amplitudes in the barbell, band, and American hip thrusts

	Barbell	Band	American
Mean			
Upper gluteus maximus	69.5 ± 32.6*†	49.2 ± 26.5	57.4 ± 34.8
Lower gluteus maximus	86.7 ± 27.0	79.2 ± 29.9	89.9 ± 32.4
Biceps femoris	40.8 ± 22.1	36.8 ± 18.0	44.2 ± 20.0
Vastus lateralis	99.5 ± 92.3	93.5 ± 70.9	87.3 ± 65.0
Peak			
Upper gluteus maximus	172 ± 91.0*	120 ± 73.8	157 ± 126
Lower gluteus maximus	216 ± 83.8	185 ± 94.4	200 ± 71.1
Biceps femoris	86.9 ± 38.8	89.4 ± 40.4	98.7 ± 44.9
Vastus lateralis	216 ± 194	185 ± 139	177 ± 128

Abbreviations: EMG = electromyography; MVIC = maximum voluntary isometric contraction.

Italicized muscles were compared nonparametrically.

* Statistically greater than the band hip thrust.

† Statistically greater than the American hip thrust.

Table 2 Number of subjects (% of subjects) to achieve maximal activation in each exercise

	Barbell	Band	American
Mean			
Upper gluteus maximus	11 (84.6)	1 (7.7)	1 (7.7)
Lower gluteus maximus	6 (46.2)	2 (15.4)	5 (38.5)
Biceps femoris	3 (23.1)	1 (7.7)	9 (69.2)
Vastus lateralis	6.5 (50.0)	3 (23.1)	3.5 (26.9)
Peak			
Upper gluteus maximus	10 (76.9)	2 (15.4)	1 (7.7)
Lower gluteus maximus	5 (38.5)	4 (30.8)	4 (30.8)
Biceps femoris	3 (23.1)	5 (38.5)	5 (38.5)
Vastus lateralis	6.5 (50.0)	2 (15.4)	4.5 (34.6)

Note. "Tied" values were "split"; eg, if one subject achieved the same value in the barbell and band hip thrusts, 0.5 were added to each.

Discussion

Statistically greater mean upper gluteus maximus EMG amplitude was elicited in the barbell hip thrust variation when compared with both the American and band hip thrust variations (Table 1). Moreover, the barbell hip thrust was found to elicit statistically greater EMG amplitude than the band hip thrust (Table 2). However, no further statistical differences in mean or peak EMG amplitude were observed between any of the hip thrust variations, despite the American hip thrust (91.9 ± 18.5 kg) utilizing slightly more load than the barbell hip thrust (87.4 ± 19.3 kg). This may be because of the positioning in the American hip thrust, in that the lever arm from the bench to the hips is shorter, thus resulting in a smaller moment arm, so a larger load would be needed to yield similar moment requisites.

Nevertheless, as expected, the barbell, band, and American hip thrust conditions all displayed very high levels of mean EMG amplitude in the upper gluteus maximus (69.5 ± 32.6%, 49.2 ± 26.5%, and 57.4 ± 34.8%, respectively) and lower gluteus maximus (86.7 ± 27.0%, 79.2 ± 29.9%, and 89.9 ± 32.4%, respectively). These results show that all 3 exercises display greater EMG amplitude in the lower gluteus maximus than the suggested threshold of 60% of MVIC for the development of muscular strength and size and that the barbell hip thrust also displays greater EMG amplitude in the upper gluteus maximus when compared with the American and band hip thrust variations.[49,50] Additionally, these findings demonstrate the mean EMG amplitude elicited by loaded hip thrusts for the gluteus maximus is markedly greater than what has been reported in an unloaded bridge.[51] This is to be expected, as other unloaded exercises have failed to elicit similar amplitudes compared with their loaded counterpart. For example, Paoli and colleagues[52] noted a 31% difference between vastus lateralis EMG in bodyweight and 70% 1-repetition maximum squats. In a wider context, this seems to be because intensity of load is a key driver of muscle activation, as a recent study demonstrated in the leg press exercise,[53] and one view of unloaded exercises is that they are simply loaded exercises involving very low intensity of load.

It should be noted that the barbell hip thrust offers potential advantages over the band and American hip thrusts. Owing to strength curve alterations in elastic implements,[31,32] the barbell hip thrust provides a more consistent hip extension moment requisite throughout the movement compared with band hip thrust. Moreover, the barbell hip thrust has a more graded learning curve than the American hip thrust, as one does not have to learn pelvic control (PPT) to perform the barbell hip thrust. However, if increased biceps femoris EMG amplitude is desired, then the American hip thrust appears to be a better option when compared with the barbell and band hip thrust variations. While there were large interindividual variations in terms of which exercise elicited the greatest EMG amplitude in each muscle (Table 2), it is worth noting that 11 and 10 out of the 13 subjects exhibited the greatest mean and peak upper gluteus maximus EMG amplitude, respectively, during performance of the barbell hip thrust.

A key limitation of our study was that because bands were used for the band hip thrust, estimating subjects' 10RM was not possible using the methods described by Baechle and Earle.[38] In the band hip thrust, the loads were estimated by equating loads used during the barbell hip thrust with peak forces elicited during unpublished pilot data collection using a force plate and slight adjustments were made based on feedback from the subjects. Therefore, loads used during the band hip thrust elicited similar peak ground reaction forces to those used during the barbell hip thrust. Thus, the 10RM used in the band hip thrust may not be equivalent in terms of intensity of load to that during the barbell and American hip thrust conditions. Since the EMG outcomes were similar and, subjectively, subjects tended to fatigue in a similar manner during the band hip thrust trials, it is presumed that bands used were approximately, albeit not exactly, 10RM. Nevertheless, if exact 10RM loads were used in comparing the barbell, band, and American hip thrust conditions, it is conceivable that different results might have been obtained.

Another limitation of our study was that it was performed only in young, resistance-trained female subjects. Thus, a very homogenous sample was used and caution is required in extrapolating these results to other populations, including untrained individuals, males, and the elderly. Therefore, it seems advisable that this experiment should be replicated in different populations.

Finally, our study was limited in that the kinematic differences between the 3 loaded hip thrust variations were not explored. By observation, it seems that barbell and band hip thrusts involve a greater range of movement than the American hip thrust exercise variation. In addition, it may be the case that both EMG amplitudes of the gluteus maximus and biceps femoris and of the hip extension moment vary differently with changing hip angle between the 3 exercise variations, but since no measurement was taken of these variables with changing hip angle, this remains unclear. Moreover, our study only considered the effect of 10RM, and different loads and set and repetition schemes should be examined. Finally, given emerging evidence that combining free weight exercise with resistance bands enhances strength in the bench press and back squat,[54,55] it is conceivable that similar benefits could be achieved from a combined approach in the hip thrust. This hypothesis also warrants further investigation.

Although greater upper gluteus maximus EMG amplitude was observed in the barbell hip thrust, exercise selection should be made based on other factors as well. Individuals with extension-induced low back pain may prefer the American hip thrust, as it involves PPT, which reduces the risk of lumbar hyperextension and therefore hyperextension-induced pathology, such as spondylolysis.[56] For some, band hip thrusts may be preferable to either the American hip thrust or the barbell hip thrust, as bands can be more comfortable on the hips, are more convenient due to their portable nature, or are more motivating, as some feel the gluteus maximus activating to a greater degree with bands than with the barbell hip thrust, as evidenced by those who experienced greater gluteus maximus EMG amplitude in the band hip thrust variation.

Nevertheless, for developing the gluteus maximus, the barbell hip thrust may be the best single option for a majority of lifters. It seems to provide more constant hip extension moment requisites throughout the whole range of motion (which is not the case with the band hip thrust), requires little motor learning with regards to pelvic control (which is not the case with American hip thrust), was found to involve the greatest mean EMG amplitude in the upper gluteus maximus and lower gluteus maximus in 11 out of 13 subjects in this study, and involved mean EMG amplitude that was above the recommended threshold of 60% of MVIC for both the upper gluteus maximus and lower gluteus maximus (which was not the case with the American hip thrust and band hip thrust, as both failed to achieve 60% MVIC in mean upper gluteus maximus EMG amplitude). However, exercise prescriptions should revolve around individual goals; therefore, the American hip thrust may be best to target the hamstrings, while the band hip thrust may be best in conditions where a barbell is not accessible or comfortable.

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