Comparison Between Back Squat, Romanian Deadlift, and Barbell Hip Thrust for Leg and Hip Muscle Activities During Hip Extension

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Abstract

Delgado, J, Drinkwater, EJ, Banyard, HG, Haff, GG, and Nosaka, K. Comparison between back squat, Romanian deadlift, and barbell hip thrust for leg and hip muscle activities during hip extension. *J Strength Cond Res* 33(10): 2595–2601, 2019—This study compared muscle activities of vastus lateralis (VL), biceps femoris (BF), and gluteus maximus (GM) during the back squat (SQ), Romanian deadlift (RDL), and barbell hip thrust (BHT) exercises performed with the same load (60 kg) and at one repetition maximum (1RM). Eight men with a minimum of 1 year's lower-body strength training experience performed the exercises in randomized order. Before each exercise, surface electromyography (EMG) was recorded during a maximal voluntary isometric contraction (MVIC) and then used to normalize to each muscle's EMG during each trial. Barbell hip thrust showed higher GM activity than the SQ (effect size [ES] = 1.39, $p = 0.038$) but was not significantly different from RDL (ES = 0.49, $p = 0.285$) at 1RM. Vastus lateralis activity at 1RM during the SQ was significantly greater than RDL (ES = 1.36, $p = 0.002$) and BHT (ES = 2.27, $p = 0.009$). Gluteus maximus activity was higher during MVIC when compared with the 60 kg load for the SQ (ES = 1.29, $p = 0.002$) and RDL (ES = 1.16, $p = 0.006$) but was similar for the BHT (ES = 0.22, $p = 0.523$). There were no significant differences in GM (ES = 0.35, $p = 0.215$) and BF activities (ES = 0.16, $p = 0.791$) between 1RM and MVIC for the SQ. These findings show that the RDL was equally as effective as the BHT for isolating the hip extensors, while the SQ simultaneously activated the hip and knee extensors.

Key Words: gluteus maximus, biceps femoris, vastus lateralis, EMG, root mean square

Introduction

Hip extension force is important for accelerating the body's upward and forward movement such as during sprinting and jumping (18). To increase force production during hip extension, the back squat (SQ), Romanian deadlift (RDL), and barbell hip thrust (BHT) are often used in training. The SQ involves moving both the hip and knee through flexion to full extension, eliciting substantial activation of the hip and knee musculature (5). The RDL is commonly used with the aim of strengthening the gluteal and hamstring muscle groups as well as the spinal erectors (19,20). The RDL has also been considered to be crucial for the development of weightlifting movements such as the clean and snatch (12). It has been suggested by Contreras et al. (7) that the BHT is superior to the SQ in eliciting higher gluteal muscle activity, developing terminal hip extension strength in the gluteus maximus (GM) thereby increasing horizontal force production, and increasing the contribution of the GM relative to the hamstrings during hip extension movement. Although the BHT has gained recent popularity, there is a lack of evidence to support the notion that the BHT does in fact increase horizontal force production of the hip or elicits higher GM activity than the SQ or RDL in athletic populations.

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Previous research by Bishop et al. (3) examined the effects of an 8-week BHT strength program on sprint performance and reported that the use of the BHT did not transfer into improvements in sprint performance. Conversely, Contreras et al. (9) favored the BHT for improving 10- and 20-m sprint times over the front squat, although it is important to note that the subjects in the study had no previous experience with the BHT but had 1 year of SQ experience. Therefore, superiority of training adaptation for the BHT over the front squat would be expected, as the introduction of a novel training stimulus (i.e., BHT) is likely to elicit higher adaptation over 6 weeks than continuing a stimulus to which they were already accustomed (i.e., SQ). In addition, Andersen et al. (2) showed higher GM activation during the BHT when compared with the barbell deadlift and hex bar deadlift, with superior biceps femoris (BF) activity seen during the barbell deadlift. Further study by Contreras et al. (8) also reported that the peak activity of the upper and lower GM and BF was greater during the BHT when compared with the SQ, but no significant differences were found between the exercises for peak vastus lateralis (VL) activity.

While the study by Contreras et al. (8) reported differences in muscle activation between the SQ and BHT, there seems to be several limitations to the methodology used. First, Contreras et al. (8) recorded electromyography (EMG) from the upper and lower GM. However, these sites do not conform to the Surface EMG for Non-Invasive Assessment of Muscles (SENIAM) guidelines for collecting EMG data (13). Second, "*manual resistance*" was used during the normalization protocol for the VL, as well as a "standing glute squeeze" to normalize GM EMG signals, but it was unlikely that an adequate fixation necessary for maximal activation of the muscles involved was achieved (14). Furthermore, Contreras et al. (8) had subjects performing 10 repetitions with a predicted 10 repetition maximum (10RM), which is estimated to be approximately 75% of the 1RM (10), thus it seems unlikely that maximal muscle activation was achieved during any exercise. It is necessary to compare the SQ and BHT during an actual 1RM using SENIAM guidelines, providing an indication of muscular activities during maximal effort movement. Moreover, as the BHT provides a movement with limited range, there are usually higher loads associated with its 1RM and would therefore have a relatively higher load for the same relative intensity, such as 60% of 1RM when compared with the SQ and RDL. Investigating muscle activation differences with the same absolute standardized submaximal load (e.g., 60 kg) across exercises would highlight activation differences without load variation. It is also important to assess muscle activities during a standardized maximal voluntary isometric contraction (MVIC) to normalize the muscle activities recorded during exercise (17).

Therefore, the aim of this study was to compare the SQ, RDL, and BHT at 1RM and at a standardized load (60 kg) for muscle activities of VL, BF, and GM during hip extension. It was hypothesized that the SQ would elicit similar GM and BF activation when compared with the RDL and BHT at 1RM and 60 kg, while VL activity would be higher in the SQ when compared with those of the RDL and BHT at 1RM and 60 kg.

Methods

Experimental Approach to the Problem

Electromyography of the hip and knee extensors was recorded during the SQ, BHT, and RDL while subjects lifted a standardized 60 kg and exercise-specific 1RM load. Subjects were asked to attend one familiarization session followed 3–7 days later by a 3-hour testing session to compare the SQ, RDL, and BHT for EMG activities of VL, BF, and GM.

Electrodes were placed on the GM, BF, and VL according to the SENIAM guidelines (13). After this, subjects performed a 5-minute standardized warm-up on a stationary cycle ergometer and 20 body mass squats. This was followed by an EMG normalization protocol on an isokinetic dynamometer (Biodex System 3 Pro; Biodex Medical System, Shirley, NY, USA) to record EMG during a maximal voluntary isometric contraction (MVIC). After the normalization session, subjects were given a 10-minute rest before performing the exercises (i.e., BHT, SQ, and RDL) to 1RM, including a warm-up set with a submaximal load of 60 kg and a 10-minute rest between exercises. Electromyography from the 3 muscles was continuously recorded during these trials.

Subjects

Eight resistance-trained men who had a minimum of 1 year of lower-body resistance-training experience, and could perform an SQ with a load of at least 150% of their body mass to a depth in which the top surface of the thighs was lower than the top of the knees, were recruited. In the familiarization session, the subjects performed 10 repetitions of each exercise with a standard 20 kg weightlifting barbell to ensure proper lifting technique of each exercise. The sample size of 8 subjects was estimated using G*Power 3.1 (11) for a within-subject repeated-measures analysis of variance (ANOVA) ($\alpha = 0.05$, $\beta = 0.80$) to detect differences (effect size [ES] = 0.40) in EMG activity of GM, VL, and BF for the 3 different exercises (i.e., BHT, SQ, and RDL) over 2 intensities (60 kg and 1RM). The average ± *SD* (range) age, height, and body mass of the subjects were 25.0 ± 3.3 (18–30) years, 177.9 ± 6.6 (169–177) cm, and 84.0 ± 6.5 (74.5–91.5) kg, respectively. Subjects abstained from their regular training between 3 and 7 days before the testing sessions. The experimental procedures were approved by Edith Cowan University's Human Research Ethics Committee and were in agreement with the principles of the Declaration of Helsinki. The subjects were briefed on the study procedures and informed consent was obtained in writing before participating in the study and were informed that they could withdraw from the study at any time.

Procedures

One Repetition Maximum Assessment. Every testing session was supervised by a Certified Strength and Conditioning Specialist to ensure proper lifting technique under maximal loads. Each subject performed the 3 exercises inside a power rack with safety holes spaced 2.54 cm apart, by following the National Strength and Conditioning Association protocol (10). A warm-up with light resistance that easily allowed 10 repetitions was performed. After a 1-minute rest period, a load of 15–20 kg was added to the barbell and each subject was instructed to perform 3–5 repetitions, followed by a 2- to 4-minute rest period. Load was gradually increased, and this process was repeated until a body mass was reached where failure of technique occurred, or the subject was not able to perform more than one repetition. There were 3–4 attempts to identify maximal weight lifted. The 1RM was recorded as the highest successfully lifted barbell load with correct technique.

For the SQ, each subject was asked to place the bar over the upper trapezius in a high-bar position and continue to flex the hips and knees until the top of the thighs were lower than the top of the knees, maintaining a neutral spine alignment. For the BHT, peak barbell height was recorded at the point of maximal hip extension during the initial repetitions of the warm-up by placing a wooden stick through the highest hole in which the safety pins insert into the power rack. Each subject was asked to thrust the barbell to this height during each test and received constant feedback to ensure there was no barbell tilt at the top. This height was kept constant by requiring the subject to hit the wooden stick with the barbell every repetition. One repetition maximum was recorded as the highest lifted load until he could not reach peak barbell height at the end of the concentric action. Each subject was asked to place his upper back on a bench 40-cm high, with the barbell placed at the crease of his hips with a barbell pad to minimize discomfort. The subjects were instructed to extend through the hips, with their feet firmly planted on the ground. For the RDL, the bar was placed on a rack set at the subject's hip level. Each subject was asked to use weightlifting straps to prevent his grip from being a limiting factor. They were instructed to stand with the weight, take 2 steps back out of the rack, and perform an RDL while maintaining a neutral spinal alignment and extending through the hip. Range of motion in the RDL was standardized to the barbell reaching the bottom of the patella for every subject. One repetition maximum was recorded as the highest lifted load with correct technique or until the subject could not reach peak barbell height at the end of the concentric (upward) motion.

Electromyography Recording and Analyses. All skin preparation procedures were followed according to the SENIAM guidelines, and each electrode was tested to ensure a reading of less than 5 kΩ. Electromyography signals were recorded using pairs of silver chloride surface electrodes (2-cm diameter, Noraxon Dual Electrodes; Noraxon USA, Inc., Noraxon, Scottsdale, Arizona, US) through a wireless EMG system (Zero Wire System; Aurion, Milano, Italy) recording at 2,000 Hz using a telemetry transmitter (Wave Wireless; Cometa Systems, Milan, Italy), which was analyzed using LabChart 8 software (PowerLab system, version 6.1.3; ADInstruments, NSW, Australia). All electrodes were placed on each subject's dominant side. For the VL, electrodes were placed at two-thirds of a line measured by a measuring tape, connecting the anterior superior iliac spine to the lateral side of the patella, in the direction of the muscle fibers. Electrodes were placed at 50% of a line measured by a measuring tape, connecting the ischial tuberosity and the lateral epicondyle of the tibia for the BF, and at 50% of a line connecting the sacral vertebrae and the greater trochanter for the GM.

To normalize EMG activity of the VL, BF, and GM during the SQ, RDL, and BHT, EMG activity of each muscle during a maximal voluntary isometric contraction (MVIC) was recorded based on Konrad's (14) proposed test positions and comprised 3 MVICs for each muscle group individually, to assess maximal EMG activity. Electromyography root mean square (RMS) during an MVIC was recorded during a one second window at peak torque produced in the MVIC. Electromyography RMS was calculated using LabChart 8 software and was recorded during the concentric phase of each exercise at 1RM and 60 kg. Differences in maximal activation (MVIC to 1RM) and changes between the 3 exercises were determined during the concentric phase of each exercise. Each subject was seated and strapped to the isokinetic dynamometer with a hip angle of 90° and was asked to maximally extend and flex for 3 repetitions at 3 different positions. For the VL, subjects were asked to maximally extend their knee fixed at 70° of flexion (where 0° is the knee fully extended). For the BF, the subjects were asked to maximally flex their knee set at the same angle of 70° of flexion. Finally, for the GM, subjects were asked to lie prone and maximally extend their hip with their upper leg fixed at 180° of hip flexion (i.e., full hip extension). They were given 1-minute rest between MVICs and 2–3 minutes of rest between muscle groups.

Statistical Analyses

Data analysis was completed in SPSS statistical analysis software (Version 25; IBM Corporation, Armonk, NY, USA). One-way ANOVAs with repeated measures were used to analyze for differences in EMG RMS for each muscle group (i.e., GM, VL, and BF) between the 3 different exercises with maximal loads (1RM) as well as the intensities (%1RM) lifted during a 60 kg repetition. Where a statistically significant effect was identified, univariate statistics (least significant differences) were used to identify between which pairs statistically significant differences lay. Differences were determined to be statistically significant at $p \leq 0.05$. Results are expressed as mean difference ±95% confidence interval, Hedge's g ES, and p value. Qualitative descriptors of standardized ES were assessed using the criteria: trivial, 0.0–0.19; small, 0.2–0.59; moderate, 0.6–0.79; and large, >0.80 (6).

Results

Exercise

The average ± *SD* (range) 1RM load lifted for the SQ, RDL, and BHT was 144.0 ± 19.2 (117–180) kg, 166.9 ± 21.0 (145–210) kg, and 164.1 ± 13.9 (135–180) kg, respectively (Table 1). The subjects lifted lighter loads for the SQ when compared with the RDL (22.9 ± 17.8 kg, ES = 1.19. $p = 0.019$) and the BHT (20.1 ± 15.4 kg; ES = 1.05. $p = 0.018$). The 60 kg load relative to the 1RM load was 42.3 ± 5.5% for the SQ, 36.4 ± 4.2% for the RDL, and 36.8 ± 3.5% for the BHT.

Gluteus Maximus Electromyography

As shown in Figure 1, the RMS of the SQ for the 60 kg load was smaller than that of the BHT (ES = 1.36, $p = 0.008$), but not significantly different from that of the RDL (ES = 0.37, $p = 0.325$). For the 1RM load, no significant differences in RMS were evident between the RDL and SQ (ES = 0.57, $p = 0.127$) as well as the RDL and BHT (ES = 0.49, $p = 0.285$), but the RMS of BHT was greater than that of SQ (ES = 1.39, $p = 0.038$). When comparing with the RMS during MVIC, the SQ (ES = 1.29, $p = 0.002$) and RDL (ES = 1.16, $p = 0.006$) showed smaller RMS during the 60 kg load, but the BHT showed no such difference (ES = 0.22, $p = 0.523$). There were no significant differences in RMS when comparing the MVIC and the 1RM for the SQ, RDL, and BHT (ES = 0.35, $p = 0.215$; ES = 0.08, $p = 0.806$; and ES = 0.30, $p = 0.375$, respectively).

Biceps Femoris Electromyography

No significant differences in the RMS of the BF were observed between the SQ and BHT (ES = 0.98, $p = 0.075$) as well as the SQ and RDL (ES = 0.35, $p = 0.326$) for the 60 kg load (Figure 2). In addition, no significant differences were evident when comparing the BHT with the RDL (ES = 0.71, $p = 0.078$) for the 60 kg load. For the 1RM load, no differences were observed when comparing the SQ to BHT and RDL (ES = 0.69, $p = 0.239$ and ES = 0.38, $p = 0.181$, respectively), and BHT to RDL (ES = 0.33, $p = 0.508$). When comparing with MVIC, no differences in RMS were found for the SQ (60 kg: ES = 0.69, $p = 0.101$, 1RM: ES = 0.16, $p = 0.791$), RDL (60 kg: ES = 0.54, $p = 0.124$, 1RM: ES = 0.60, $p = 0.308$), and the BHT at 60 kg (ES = 0.14, $p = 0.608$), but higher BF activity was observed during the BHT at 1RM (ES = 0.99, $p = 0.001$).

Table 1
One repetition maximum load (1RM) and its relative value to the body mass (1RM/BM) of back squat, Romanian deadlift, and barbell hip thrust for each subject (A–H), and the mean and *SD* of 8 subjects.

	Back squat		Romanian deadlift		Barbell hip thrust	
Subject	1RM (kg)	1RM/BM	1RM (kg)	1RM/BM	1RM (kg)	1RM/BM
A	130	1.44	150	1.64	170	1.86
B	180	2.00	170	1.87	180	1.98
C	145	1.81	170	2.13	153	1.91
D	155	1.72	155	1.72	165	1.83
E	145	1.81	180	2.24	170	2.11
F	130	1.67	155	1.97	135	1.71
G	117	1.57	145	1.95	170	2.28
H	150	1.75	210	2.45	170	1.98
Mean	144.0	1.72	166.9	2.00	164.1	1.96
SD	19.2	0.17	21.0	0.27	14.0	0.18

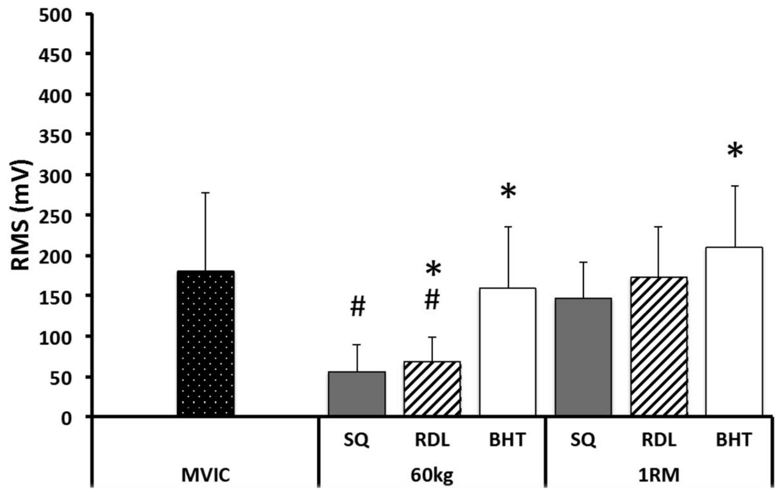

Figure 1. Mean root mean square (RMS) values of gluteus maximus EMG activity (mean ± *SD*) during maximal voluntary contraction (MVIC) and the concentric phase of the back squat (SQ), Romanian deadlift (RDL), and barbell hip thrust (BHT) at 60 kg and one repetition maximum (1RM) load. # Significantly different ($p < 0.05$) when compared with MVIC. *Significantly different ($p < 0.05$) when compared with SQ. EMG = electromyography.

Vastus Lateralis Electromyography

For VL (Figure 3), the RMS of the SQ was greater than that of RDL and BHT for the 60 kg (ES = 7.77, $p = 0.002$ and ES = 2.54, $p = 0.001$, respectively) as well as the 1RM load (ES = 1.36, $p = 0.002$ and ES = 2.27, $p = 0.009$, respectively). In addition, the RMS of the RDL was smaller than that of the BHT with the 1RM load (ES = 0.79, $p = 0.045$). In comparison with the RMS during MVIC, the RDL and BHT showed smaller RMS for the 60 kg load (ES = 1.47, $p = 0.002$ and ES = 1.23, $p = 0.002$, respectively) as well as the 1RM load (ES = 1.11, $p = 0.003$ and ES = 0.59, $p = 0.046$, respectively), but the SQ showed greater RMS for the 1RM load (ES = 0.90, $p = 0.006$).

Discussion

The results from the current study demonstrate that the BHT elicited significantly greater GM muscle activity when compared with the SQ but was not significantly different from the RDL at 1RM (Figure 1). There were no differences in BF activity between the 3 exercises at 1RM (Figure 2), displaying higher activity during all exercises with maximal loads. Vastus lateralis activity (Figure 3) was the highest in response to the 60 kg and 1RM loads during the SQ when compared with the RDL and BHT at 1RM and 60 kg loads. Overall, the RMS during the SQ 1RM was comparable with the MVIC in all muscles recorded, but the VL activity during the RDL and BHT was lower when compared with an MVIC (Figures 1–3). In addition, the BHT elicited higher GM

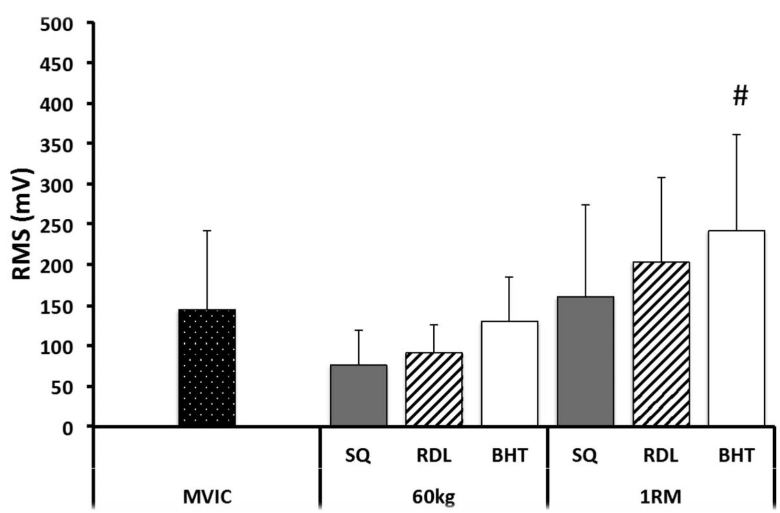

Figure 2. Mean root mean square (RMS) values of biceps femoris EMG activity (mean ± *SD*) during maximal voluntary contraction (MVIC) and the concentric phase of the back squat (SQ), Romanian deadlift (RDL), and barbell hip thrust (BHT) at 60 kg and one repetition maximum (1RM) load. #Significantly different ($p < 0.05$) when compared with MVIC. EMG = electromyography.

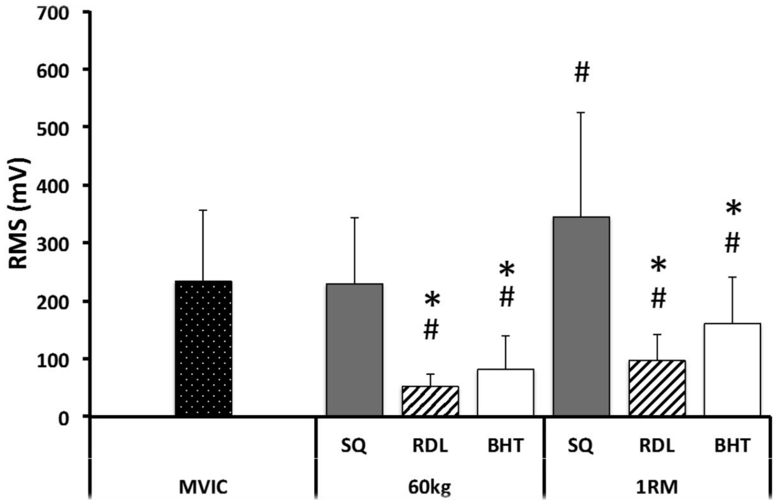

Figure 3. Mean root mean square (RMS) values of vastus lateralis EMG activity (mean ± *SD*) during maximal voluntary contraction (MVIC) and the concentric phase of the back squat (SQ), Romanian deadlift (RDL), and barbell hip thrust (BHT) at 60 kg and one repetition maximum (1RM) load. #Significantly different ($p < 0.05$) when compared with MVIC. *Significantly different ($p < 0.05$) when compared with SQ. EMG = electromyography.

activity in response to the 60 kg load when compared with the other exercises. From these results, we conclude that the greater concurrent activation in the hip and knee extensors makes the SQ a more appropriate training exercise for sporting applications, while the BHT and RDL are equally appropriate for isolating the hip extensors.

The main purpose of this study was to investigate which exercise would achieve the greatest muscle activity across the 3 different muscle groups (i.e., GM, BF, and VL). Although GM activity was greatest during the BHT, there was still high GM activity relative to the MVIC in the 1RM for the SQ (Figure 1). In addition, there were no significant differences in the GM activity between 1RM and MVIC, although the loads lifted were significantly lower in the SQ at 1RM when compared with the other exercises. The subjects reported that the BHT was an uncomfortable exercise to perform with maximal loads. Therefore, although the BHT elicits the greatest GM activity, the SQ may be a good alternative if the BHT is an uncomfortable exercise for athletes. If the athlete has difficulty getting into the bottom position of the squat, GM activation may not be as high (4); thus, the inclusion of BHT and RDL, along with enhancing SQ technique, seems appropriate to ensure even strength development throughout the anterior and posterior chain in the lower body. Furthermore, the RDL may be an excellent alternative to the BHT for eliciting high GM activity without the hip discomfort.

The long head of the BF works in synergy with the GM and is involved in the end range of hip extension as well as during knee flexion (15); thus, high hamstring activity was expected during all 3 exercises. There is no significant difference in the BF activity between the SQ, RDL, and BHT at both the 1RM and 60 kg loads, although higher BF RMS was seen during the BHT 1RM when compared with an MVIC (Figure 2). The placement of the load during the BHT across the hips supports the reliance on the BF for full hip extension with the load applying downward force against the hips. The BHT is performed in a supine position with the load resisting along the sagittal plane across the hips, thus the hamstrings were expected to elicit high activity throughout this movement. These findings agree with Contreras et al. (8) who reported higher BF activity during BHT when compared with the RDL and SQ during submaximal loads. However, there were no differences in the BF activity in the MVIC, 1RM or 60 kg loads in all exercises, indicating high BF activity during both maximal and submaximal dynamic contractions for the SQ, RDL, and BHT.

As a result of the 1RM loads lifted being significantly lower during the SQ when compared with the RDL and BHT, the fixed load of 60 kg represented a higher relative load during the SQ than the BHT and RDL. This difference in the relative intensity was not reflected in RMS values, as the BHT displayed higher average GM RMS values than the RDL and SQ at 60 kg, despite 60 kg load representing a lower relative intensity during the BHT. The ability to achieve higher activation of the GM with lower intensities may be a useful property of the BHT. To increase the joint compressive forces during knee flexion/extension exercises, antagonistic activities of flexors have been previously reported (1), which could explain the lack of difference in BF activity between the SQ and MVIC. Although the BHT was the only exercise to elicit higher BF activation than an MVIC, there were no statistically significant differences between exercises.

During BHT 1RM testing, the subjects often reported inability to go higher in weight not because of lack of strength, but due to the discomfort caused by the weight on the hip crease. Because of the load placement on the hips during the BHT, this exercise poses to be an uncomfortable movement to perform with maximal loads, even with a barbell pad. Therefore, the high activation of the GM achieved during the BHT without the use of heavy loads may be more conducive to hypertrophic or endurance training. The lack of difference seen in GM activity when compared with the MVIC and the 60 kg BHT (Figure 1) may be a result of the supine position that the exercise was performed in, which allows for an isometric contraction of the GM at the top of the movement against the load. This position, where there is full hip extension, is comparable with the position used in the MVIC measure, in which the subjects contracted the GM against the dynamometer's attachment arm at 180° of hip extension and may provide the same level of activity as the top of the BHT.

In addition to the GM, the knee extensors also play an important role in functional movements of the lower body such as running and jumping. As shown in Figure 3, VL RMS was significantly higher with a "large" effect size during the SQ when compared with the BHT and RDL. Vastus lateralis activity during an MVIC was significantly higher than the activity observed in a 1RM RDL and BHT, indicating little movement through the knee joint during these 2 exercises. The RDL and BHT both focus on lifting the load using the hip, with the knee in a fixed position and the knee extensors providing stability throughout the movement. In addition, the movement during the BHT starts in a position of approximately 90° of knee flexion, and this angle is maintained throughout the exercise. The SQ, however, uses the hip as well as the knee extensors to lift the load from a position of full flexion to full extension, demonstrated by the SQ showing higher VL activity during 1RM when compared with MVIC. Vastus lateralis activity was also significantly higher in the SQ when compared with the BHT and RDL at 1RM and 60 kg. Therefore, as the SQ displays high activity of the knee and hip extensors, it may be a more appropriate exercise to use when training to improve athletic movements involving simultaneous extension of both the knee and hip.

This study showed significant differences in the BHT and the SQ for VL activity between dynamic and isometric contractions, which disagrees with previous findings by Contreras et al. (8). In the study by Contreras et al. (8), "manual resistance" was provided, which may not represent adequate or consistent fixation to evoke a true maximal isometric contraction of the VL and may underestimate muscle activity (14). By contrast, the current study showed no difference between RMS collected during an MVIC and the SQ performed with 60 kg and higher activation during submaximal dynamic contractions relative to an MVIC. This suggests that the SQ was the only exercise to elicit high levels of VL activation when compared with the other exercises at 1RM. In addition, while the BHT and RDL are good for isolating the hip extensors (i.e., BF and GM), high activity from the VL was not seen in both exercises. Furthermore, a comparison of muscle activity with a true MVIC measure is likely more appropriate for practitioners looking to determine muscle activation, based on the flaws and limitations previously highlighted.

Although the SENIAM guidelines were followed, higher levels of activity during an MVIC when compared with submaximal contractions were expected, but this was not always the case. The high activity during submaximal 60 kg dynamic contractions, seen in the GM, VL, and BF (Figures 1–3) when compared with an MVIC, highlights potential differences in activation between isometric and concentric contractions and may warrant the need for a different normalization method in further research. In addition, while the knee extension angle in this study was appropriate for maximal activation (14), the same angle was used to measure hamstring activation during knee flexion, which may have underestimated hamstring activity. It is previously stated by Konrad (14) that systematic research studies on the effectiveness of MVIC positions for maximal muscular activation are still missing; thus, the positions used for the normalization protocol may be the reason for resistance training activities exceeding the established threshold for 100% activation.

In conclusion, the BHT elicited the highest GM activity with the 1RM load when compared with the SQ, but all 3 exercises were able to elicit high levels of GM activity during 1RM loads relative to an MVIC. Notably, the BHT achieved the highest GM activation even without the need for a near-maximal external load. The BHT eliciting high GM activation agrees with previous findings by Andersen et al. (2) and Contreras et al. (8). However, although the BHT and RDL elicit higher hip extensor activity, the SQ was the only exercise to simultaneously provide high knee and hip extensor activity relative to an MVIC. The SQ simultaneously elicited high activation of the hip and knee extensors at higher loads, which may translate better to athletic performance and functional movement patterns that require forceful hip and knee extension, a conclusion supported by Bishop et al. (3), previously displaying no improvements in sprinting performance after using the BHT for 8 weeks. This study demonstrated that while the BHT elicited greater GM activity when compared with the SQ, no significant differences were seen between the BHT and RDL at 1RM. Therefore, the SQ seems to be an efficient exercise for training both hip and knee extension strength.

Practical Applications

This study demonstrates that while the BHT elicits greater GM activity when compared with the SQ, equal levels of activity were seen between the BHT and RDL at 1RM and the SQ still displayed high GM activity relative to an MVIC. Strength and conditioning coaches who aim to isolate hip extensor musculature activation may equally benefit from prescribing the BHT and RDL, although the BHT is usually perceived as the safer and easier to learn option (16). However, the SQ displayed the highest levels of knee extensor activity as well as high hip extensor activity relative to an MVIC at 1RM loads, which places the SQ as a fundamental exercise to be part of any resistance training program involving movements that encompass both knee and hip extension. In addition, the ability for the BHT to elicit higher neuromuscular activation of the GM with a submaximal load of 60 kg is an important finding, as the BHT poses to be an uncomfortable movement to perform with maximal loads. If the goal is to elicit high GM activity, heavy loads during the BHT may not be necessary to accomplish it.

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